American Foundryman

"The FOUNDRYMEN'S OWN MAGAZINE"

Brass foundry melting room. (Courtesy Wolverine Brass Works)

September 1945 — Heat Treatment of Cast Iron (p. 27). Magnesium Alloy Microporosity (p. 33). Method of Production Control (p. 45). Repair of Steel Castings (p. 48). Qualifying Castings (p. 54). Gray Cast Iron (p. 57). 1944 Patternmaking Contest (p. 64). Split Specimen Tubes for Sand Testing (p. 68). Post War Aluminum Foundries (p. 73).


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American Foundryman

SEPTEMBER, 1945 VOL. VIII, No. 2

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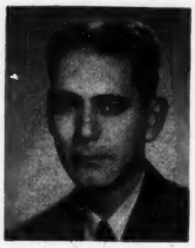
WHO ARE THE AUTHORS *In This Issue?*

The men whose names are shown on these two pages deserve the thanks of the industry for their contributions to the 1945 "Year-'Round Foundry Congress" . . . in many cases, completed in spite of cancellation of the Detroit convention.

Douglas C. Williams



Appearing in this issue: *"Split Type Specimen Tube for Elevated Temperature Sand Testing"* . . . Born in Crystal Lake, Ill. . . . Graduated from Beloit College, Beloit, Wis., in 1930 with a bachelor of science degree . . . Entered industry in 1930 as chemist, E. I. Du Pont de Nemours Co., Jackson Laboratories, Wilmington, Del. . . . Two years later became affiliated with J. R. Short Milling Co., Chicago, in a similar capacity . . . Joined the Delco-Frigidaire Div., General Motors Corp., Chicago, in 1937 as heating and air conditioning engineer . . . Was connected with the American Steel Foundries, East Chicago, Ind., as chemical engineer in the research laboratory until 1943 . . . At the present time is serving as the A.F.A. research fellow, Cornell University, Ithaca, N. Y. . . . Has been conducting research on the elevated temperature properties of sands under the direction of the Committee on Physical Properties of Foundry Sands at Elevated Temperatures, subcommittee on Steel Foundry Sands.

E. A. G. Liddiard

In this issue: see *"Cause and Control of Magnesium Alloy Microporosity"* . . . Collaborator with W. A. Baker on this I. B. F. exchange paper . . . The twenty-fourth paper of an uninterrupted series started in 1922 . . . Mr. Liddiard was born in 1903 . . . Was laboratory assistant at the Cyclops Steel Works of Messrs. Camel Laird & Co. Ltd., Sheffield, England, from 1922 to 1925 . . . He graduated from Gonville & Caius College, Cambridge, in 1928 with a bachelor of arts degree . . . Received his master of arts degree in 1932 . . . Was research chemist with I.C.I. (Synthetic Ammonia and Nitrates) Ltd., Billingham, from 1928 to 1932 . . . Appointed assistant development officer to the B. N. F. M. R. A. in 1932 . . . In 1938 was named assistant research superintendent . . . Since 1943 has been research manager.

T. E. Barlow

Author (with his associate C. H. Lorig) of current paper on *"Gray Cast Iron — Tensile Strength, Brinell Hardness and Composition Relationships"* . . . Born in Ontario, Canada, in 1910 . . . Received his bachelor of science degree at University of Michigan, Ann Arbor, Mich., in 1934 . . . That same year joined Ecorse Foundry Co., Detroit, as chief metallurgist . . . In 1936 was research engineer, Battelle Memorial Institute, Columbus, Ohio . . . Three years later (1939) was appointed technical director, Copper, Iron & Steel Development Association, Cleveland . . . Became foundry engineer, Vanadium Corp. of America, Detroit, in 1940 . . . Assumed his present position in 1944 as research engineer, Battelle Memorial Institute . . . Has written fluently for the trade journals on such subjects as copper in iron, alloying, cupola practice and other topics . . . Has prepared papers for A.F.A. annual conventions and has addressed many A.F.A. chapters . . . Is active in the Gray Iron Division, a member of that division's Executive Committee and chairman of Chill Test and Inoculation Committees . . . At present is serving as Chairman of the Central Ohio chapter . . . Member of AIME, ASM, ASTM and A.F.A.

DISCUSSION WANTED!

•

The men who are recognized on these Who's Who pages each month have spent considerable time and effort in preparing their papers for presentation herein, and the value of their findings can be materially enhanced through discussion. Since oral discussion is not possible this year, written discussion is earnestly solicited!

Members of A.F.A. owe it to these authors to take a definite interest in their work. Written discussion should be forwarded direct to A.F.A. headquarters in Chicago, for publication in future issues of *American Foundryman.*

W. H. Gunselman

Director of research and foundry engineer, Samuel Greenfield Co., Inc., Buffalo . . . Author of aluminum paper in this issue . . . Paper covers *"Post War Operations of Aluminum Foundries"* . . . Prior to his present position, the author was chief metallurgist, National Bronze & Aluminum Foundry Co., Cleveland . . Has been associated with several other midwestern foundries, where he has accumulated a vast amount of foundry knowledge . . . Is a member of ASM, ASTM, SAE and A.F.A.

W. A. Baker

Co-author, with E. A. G. Liddiard, of interesting I.B.F.-A.F.A. exchange paper on microporosity in this issue . . . Titled: *"Cause and Control of Magnesium Alloy Microporosity"* . . . Born in 1912 . . . Was assistant chemist at the Royal Mint, London, 1929-35 . . . Graduated with honors from the London University, 1934, when he received his bachelor of science degree in metallurgy . . . Became associated with the B. N. F. M. R. A. in 1935 as junior

investigator . . . Since 1939 has been senior investigator in charge of the association's researches on melting and casting of non-ferrous metals.

R. W. Lindsay

See: *"Heat Treatment Study of Pearlitic Malleable Cast Iron"* . . . Co-author, Pfc. J. E. Atherton, Jr. . . . Mr. Lindsay was born in Boston, Mass., in 1912 . . . Obtained his bachelor of science degree in chemical engineering from Tufts College, Medford, Mass., in 1933 . . . Two years later (1935) earned his master of science degree in metallurgy from Massachusetts Institute of Technology, Cambridge . . . Went on to receive his doctor of science degree in physical metallurgy in 1938 from the same institution . . . Began his industrial career (1938) as research assistant, Association of Manufacturers of Chilled Car Wheels, Chicago . . . Became associated with Sealed Power Corp., Muskegon, Mich., as research metallurgist in 1942 . . . The following year was named assistant professor of metallurgy, Pennsylvania State College, State College, Pa. . . . In 1945 resumed his affiliation with Association of Manufacturers of Chilled Car Wheels in a metallurgical capacity . . . A frequent writer for the trade press concerning various phases of cast iron metallurgy and other subjects . . . Has spoken before many technical societies . . . Co-author of the book *"The Microstructure of Chilled Car Wheel Iron"* . . . Member of A.F.A. and ASM.

Frank C. Cech

See paper entitled: *"1944 Patternmaking Contest"* . . . Born in Vienna, Austria . . . Educated in American schools and colleges . . . Started his patternmaking career in Cleveland with American Steel & Wire Co., Cuyahoga Works . . . Moved on to a similar position with Wellman, Searer and Morgan Engineering Co. and Corrigan McKinney Steel Co., both of Cleveland . . . Became pattern checker and assistant foreman while affiliated with Cleveland Automatic Machine Co., Cleveland . . . Was appointed pattern shop foreman for Allyne-Ryan Foundry Co., Cleveland. . . At present is head, patternmaking division, Cleveland Trade School, Cleveland . . . Has been active in the A.F.A. patternmaking division for many years and is now serving as Chairman of that division . . . Has written numerous articles for the trade press and for vocational magazines . . . Is well known for his A.F.A. convention papers on patternmaking and allied subjects . . . Member of A.F.A.

R. A. Pomfret

See his interesting article herein on *"Removal and Repair of Steel Casting Defects"* . . . Born in Waltham, Mass., October, 1910. . . . Earned his bachelor of science degree in metallurgical engineering at University of Alabama, Tuscaloosa, Ala., in 1934 . . . In 1935 assumed a position in the forge shop, Bethlehem Steel Co., Shipbuilding Div., Quincy, Mass . . . Was made assistant materials engineer in 1938 . . . Became materials engineer in 1944 . . . Member of ASM and ASTM.

Pfc. J. E. Atherton, Jr.

See in this issue: *"Heat Treatment Study of Pearlitic Malleable Cast Iron"* . . . Written jointly by Mr. Atherton and R. W. Lindsay . . . Co-author, Mr. Atherton, is at present a member of the armed forces serving in the United States Army . . . Born in Lemoyne, Pa., October, 1923 . . . Matriculated at Pennsylvania State College, State College, Pa., and received his bachelor of science degree in metallurgy, 1944 . . . A member of ASM.

G. D. White

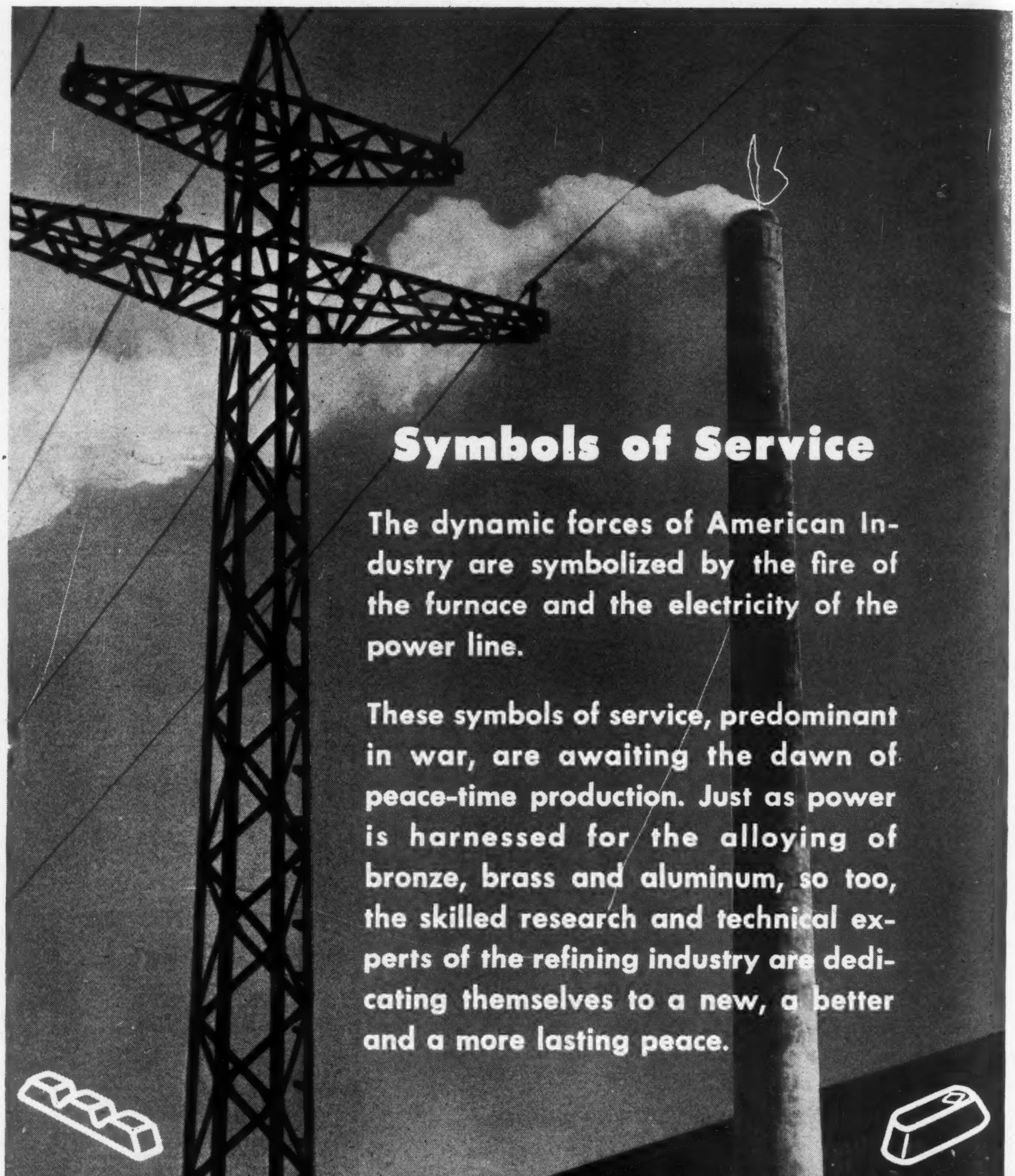
See *"A Method of Production Control"* in this issue . . . Author was born in Roswell, N. M., 1915 . . . Educational background includes extension courses from Stanford University, Palo Alto, Calif. . . . Started his business career with the Santa Catalina Island Co., Catalina Island, Calif., 1932 . . . Left that firm as superintendent in 1942 to become affiliated with Enterprise Engine & Foundry Co., San Francisco . . . Was appointed production control supervisor . . . At present is a distributor of production control methods and equipment . . . An A.F.A. member.

C. H. Lorig

Supervisor for the Battelle Memorial Institute, Columbus, Ohio . . . Part-author of paper in this issue on *"Gray Cast Iron—Tensile Strength, Brinell Hardness and Composition Relationships"* . . . Co-author is T. E. Barlow . . . Mr. Lorig is a native of St. Paul, Minn., where he was born in 1900 . . . Higher education undertaken at University of Wisconsin, Madison, Wis. . . . Merited a bachelor of science degree in 1924 . . . Went on to earn his master of science degree one year later . . . Obtained his Ph.D. in 1928 . . . Entered industry in 1925 as metallurgist for the Stowell Co., South Milwaukee, Wis. . . . The following year (1926) was research engineer, French Battery Co., Madison, Wis. . . . After two years became metallurgist, Ladish Drop Forge, Cudahy, Wis. . . . In 1929 was assistant professor, Drexel Institute, Philadelphia . . . The following year joined the staff of Battelle Memorial Institute as supervisor . . . Has written extensively for the trade press . . . Prepared numerous papers for technical society meetings and conventions . . . Is a member of the A.F.A. Gray Iron Divisions' and Steel Divisions' Executive Committee . . . Member of AIME, ASM, Institute of British Foundrymen and A.F.A.

O. O. Gammon

See paper in this issue on *"Castings Should Always Be Qualified in the Foundry"* . . . This chief tool designer was born in Wayne City, Illinois . . . Entered industry in 1925 as a machine apprentice for the Mueller Company, Decatur, Illinois . . . After a two-year apprenticeship joined Faries Mfg. Co., Decatur, Ill., and served an additional year as machine apprentice . . . Became associated with Caterpillar Tractor Co., Peoria, Ill., as tool designer in 1928 . . . Returned to Decatur in 1940 as a tool designer for Oakes Products . . . During 1940 he was affiliated with Allison Div., General Motors Corp., Indianapolis, as assistant chief tool designer . . . In 1942 joined the staff of Caterpillar Military Eng. Co., Decatur, Ill., as chief tool designer . . . At present is chief tool designer at Caterpillar Tractor Co. . . . A member of ASTE.


Symbols of Service
The dynamic forces of American Industry are symbolized by the fire of the furnace and the electricity of the power line.
These symbols of service, predominant in war, are awaiting the dawn of peace-time production. Just as power is harnessed for the alloying of bronze, brass and aluminum, so too, the skilled research and technical experts of the refining industry are dedicating themselves to a new, a better and a more lasting peace.
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COPPER COILS 1 3/8" diam.
10 cuts per min. with
32-pitch DoALL Precision

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50.8 in. per min. with
4-pitch DoALL Buttress

STEEL TUBING, welded, 1 3/4" diam.
200 cuts per min. with
10-pitch DoALL Precision

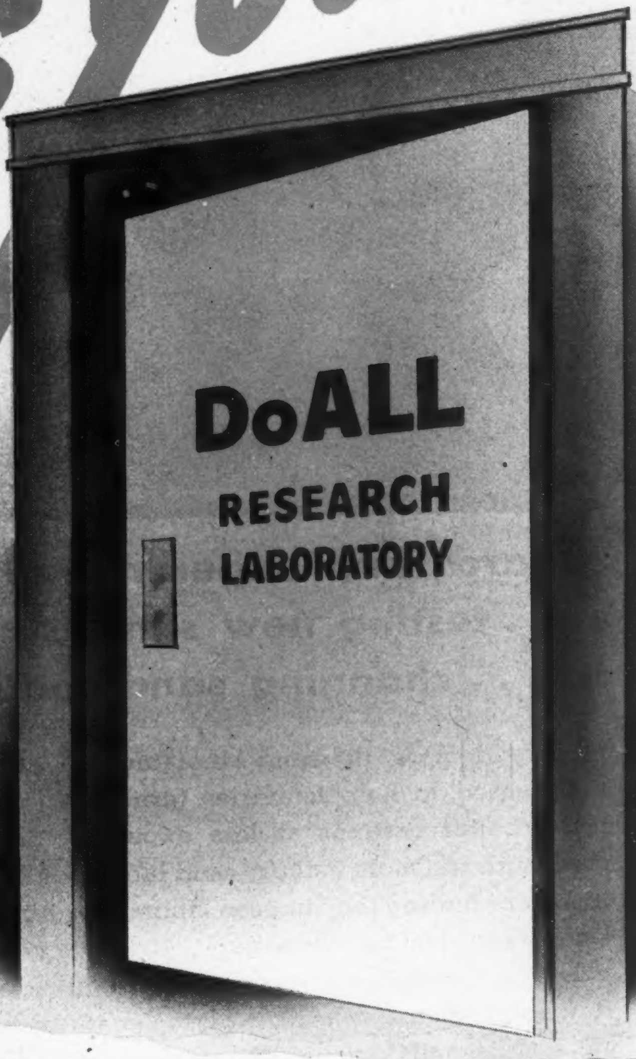
MEEHANITE 4" diam.
3 sq. in. per min. with
6-pitch DoALL Precision

DoALL TESTS SHOWED:

STEEL BEAM 1/8 x 2 1/2"
100 cuts per min. with
10-pitch DoALL Precision

ZINC 1" thick
38 lin. ft. per min. with
2-pitch DoALL Buttress

BRASS ALLOY
17.6 sq. in. per min. with
3-pitch DoALL Buttress



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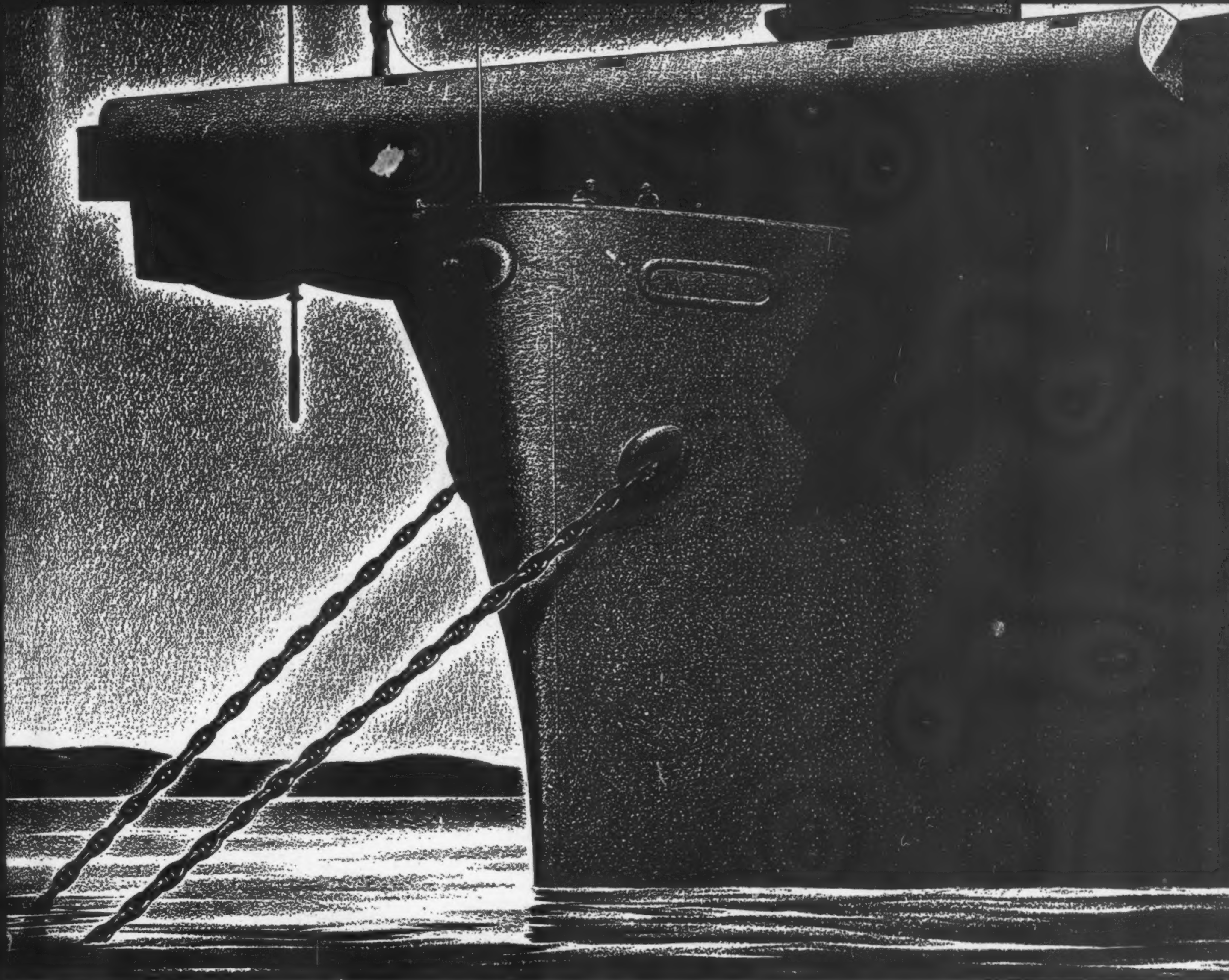
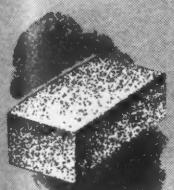



HEAT-THIRSTY
FURNACE LININGS
DRINK UP PROFITS



A SERIOUS — and preventable—loss exists in many foundries that carry on heat-treating and annealing operations. This loss results in substantially higher fuel costs, yet is not apparent. It doesn't advertise itself, like piles of gates and risers or mounds of burnt sand. However, it can be detected—even measured—with surprising ease.

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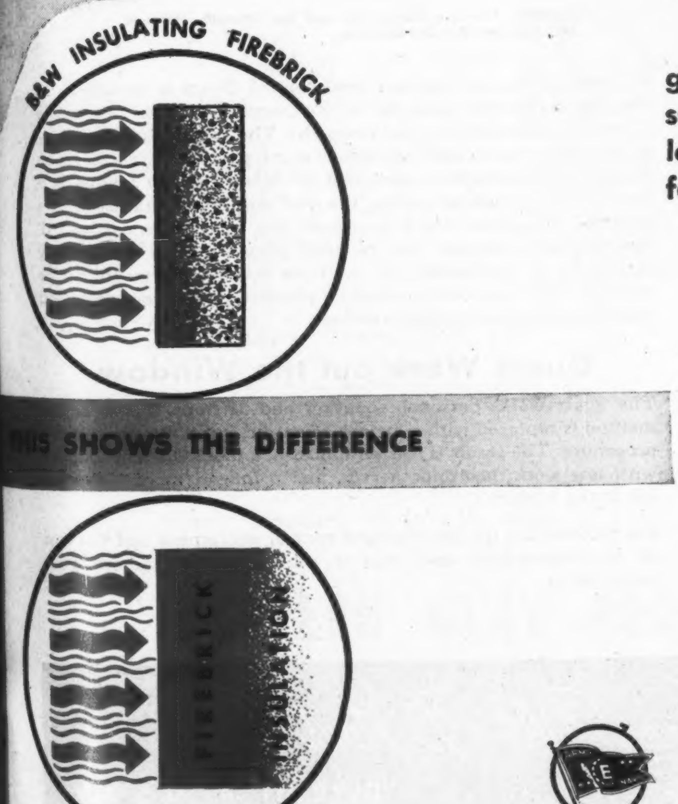

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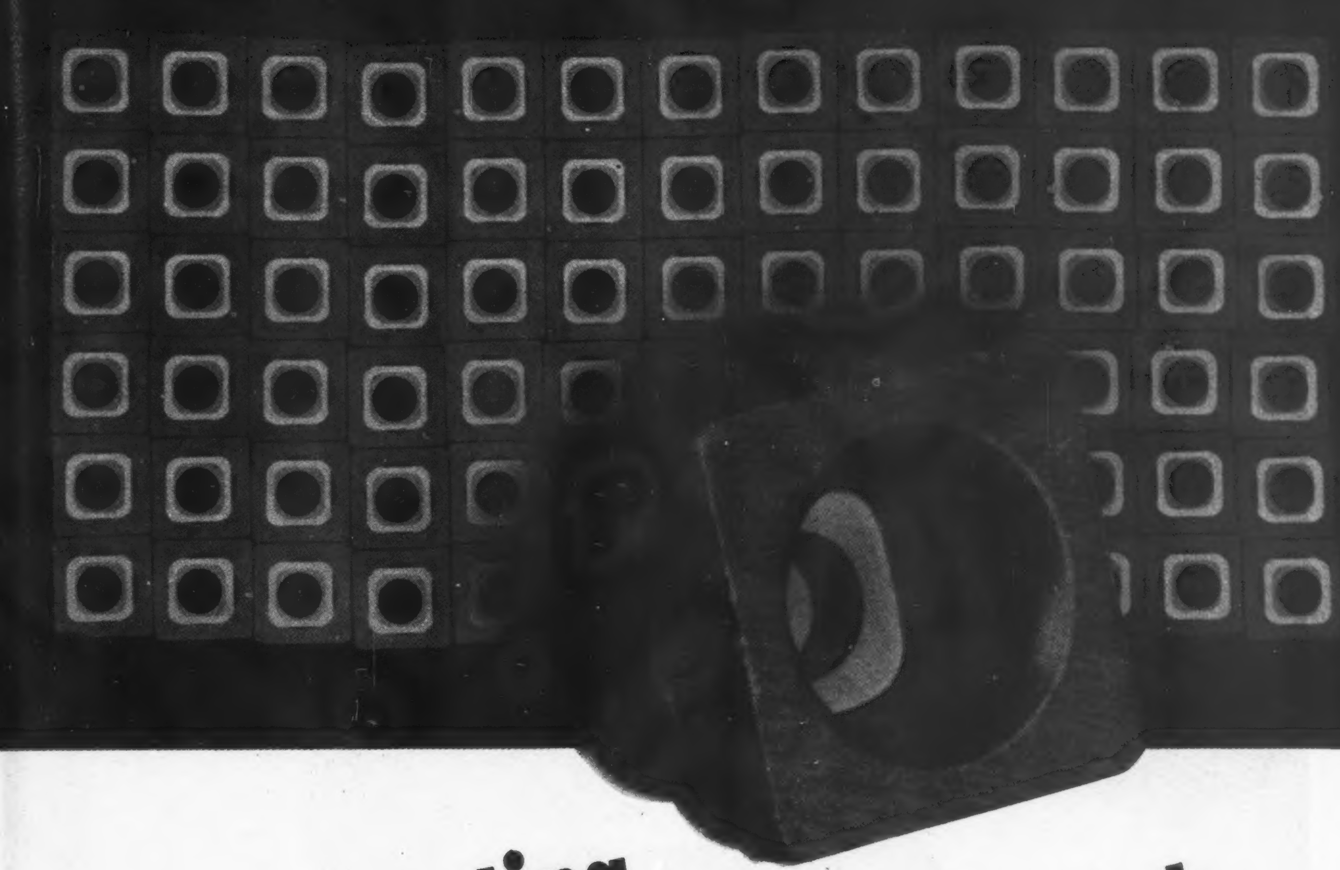
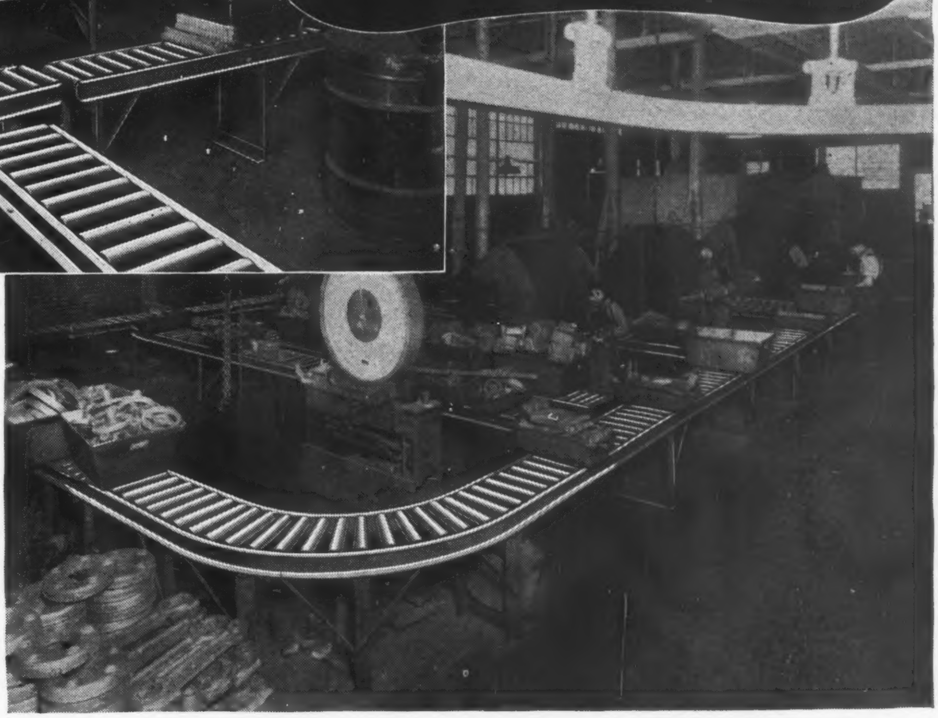
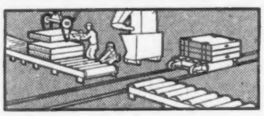
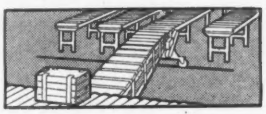
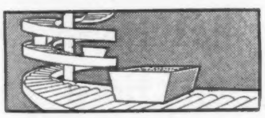
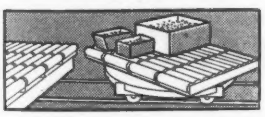












Foundry Industry Now Has Greatest Opportunity for Industrial Recognition

THANK GOD it's over!

Every man and woman who has been a part of this immense Industry during war-time can take just pride in a job superbly done—and this includes those many men in the Army, Navy, Air Corps and Government Agencies whose diligence and cooperation were of vital assistance to the American Industry Combat Team.

The exacting demands of war production have created new levels of excellence in foundry products. The need for intricate shapes in mass production quantities revealed new heights of ingenuity on the part of foundry craftsmen. Necessary high strengths and durability brought forth new peaks of metallurgical controls, research, and achievement.

No man will ever know how many millions of castings were made as our contribution to the war effort, nor how many different patterns were created, nor how many millions of tons of castings found their way into every conceivable weapon, ship, vehicle, or aircraft in supplying our combat forces with the materials of victory.

During the war years our industry learned that it can do many things which once were believed impossible. These achievements can well become the backbone of a new industrial concept of the foundries' role in the creation of America's peacetime products.

During the months ahead, foundry technicians, engineers and metallurgists can well afford to record the gains of the past few years. Much of the information so registered cannot help but become the ground work for important technical papers on foundry science, both for publication in trade journals and for presentation at the 50th ANNIVERSARY CONVENTION AND EXHIBIT of American Foundrymen's Association, to be held in Cleveland next May.

Even more value can accrue to the foundry industry by the presentation of technical reports on the engineering and metallurgical performance of foundry products in the thousands of applications made during the war. Advances in foundry science, coupled with knowledge of performance, backed by millions of hours of combat service as positive evidence of excellence, should furnish material for an unending supply of articles, talks and discussions between members of our industry and the engineers, metallurgists and users of metal products.

Never again will we have given to us an opportunity so far-reaching as exists at this moment. The products of our industry have been proved in wartime performance. Every member of the foundry industry should be vitally concerned with spreading this knowledge where it will be of utmost benefit and usefulness.

George K. Dreher

GEORGE K. DREHER, *Director*
American Foundrymen's Association

GEORGE K. DREHER, plant manager, Ampco Metal, Inc., Milwaukee, is a member of the Executive Committee, Brass and Bronze Division, and also a member of the Association's Board of Directors. He is chairman of a new A.F.A. brass and bronze committee Recommended Practices Committee on Centrifugal Casting. Mr. Dreher is a staunch supporter of the Wisconsin chapter and served as secretary, vice-president and, for two years, as president.

A.F.A. GOES to CLEVELAND in '46

50th Anniversary Year to Feature First Peacetime Convention and Exhibit

JAPAN surrendered on Aug. 14. One week later A.F.A. announced plans to stage the 50th Anniversary Foundry Congress and Foundry Show in the Cleveland Auditorium May 6-10, 1946. Thus the foundry industry will begin its first year of peace-time production, a year of reconversion and adjustment, with the impetus of what is expected to be one of the finest and most enthusiastic meetings ever held by your Association. Adding to the importance of the event are plans, now under way, that may enable the holding of an International Foundry Congress at the same time, the first held in America since 1934.

Look for War Developments

In organizing the technical program for 1946, every effort will be made to bring forth papers describing outstanding developments in foundry practice which have played a tremendous part in war-time castings production and which hitherto have been under the veil of censorship. Many of these developments, it is known, are eagerly awaited by the foundry industry and undoubtedly will be of vital service in the production of peace-time commodities.

While V-J Day occurred too recently for the release of this material by Ordnance, in all likelihood such release will not be long forthcoming. Presentation of this material at the Cleveland Convention would in itself be a tremendous drawing card for foundrymen from all over the country.

Another important stimulus to attendance arises from cancelation of the 1945 convention which was scheduled for Detroit. Loss of this opportunity for discussion of mutual problems simply means that thousands of men, tied down for years by transportation difficulties, regulations, priorities and a determination "to get the job done," now will look forward eagerly to a peace-time convention of their industry, "with the brakes off."

Plan Operating Exhibit

Seldom has an A.F.A. Foundry Show been announced with such a backlog of enthusiasm on the part of the manufacturers of equipment and supplies for foundry use. Even prior to the Detroit meeting, planned as a non-exhibit convention, numerous inquiries were received for exhibit space in 1945. In recent months interest has mounted in the Association's plans for the 1946 exhibit.

Invitation will shortly be extended to the equipment and supply industry to display its products at the 50th Anniversary Convention, with opportunities for operating exhibits such as have not been available in a number of years. It is believed that full advantage will be taken of this opportunity for demonstrating the value of new and improved products and materials to thousands of foundrymen eager to improve the quality of their castings and to reduce production costs in the face of renewed commercial competition.

Many manufacturers undoubtedly will find it possible during the next nine months to transfer new products and refinements from their drawing boards to the floor of the Cleveland Auditorium. The value of the exhibits to the foundry industry has been proved countless times, and the service that the exhibits will perform at the 50th Anniversary Foundry Show, by aiding the reconversion of the castings industry, will be incalculable.

Hope for International

If at all possible, it is intended that the 1946 meeting may be staged as an International Foundry Congress. Effort now is being made to stimulate attendance by foundrymen from England, France, Belgium, Russia, Mexico, South America, South Africa, Australia, China and

(Concluded on Page 87)

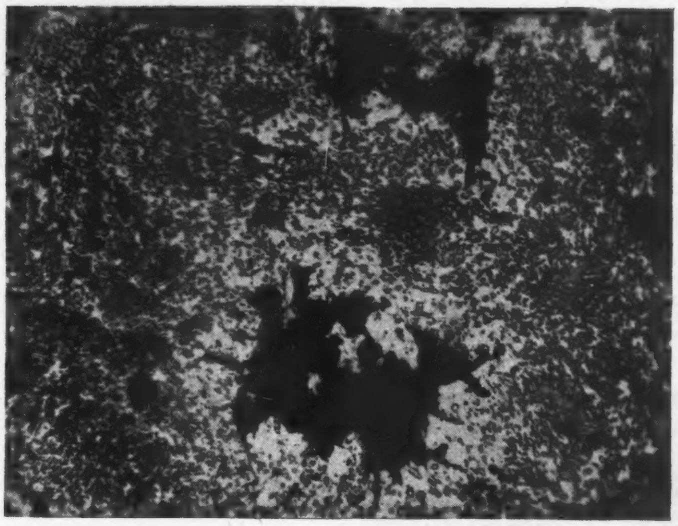


Fig. 1—Microstructure of the iron as received from manufacturer. Nital etch. 500X.

Heat Treatment Study of

Pearlitic Malleable Cast Iron

• An investigation of certain phases of the heat treatment of pearlitic malleable cast iron—an attempt to show a correlation between the microstructures and hardness values obtained. Heat treatments—oil quenching followed by tempering, and isothermal transformation at various subcritical temperatures. Concluding that pearlitic malleable cast iron responds to heat treatments similarly to steel.

By R. W. Lindsay, Metallurgist,
Association of Manufacturers of Chilled Car Wheels,
Chicago,
and
J. E. Atherton, Jr., Graduate,
Department of Metallurgy, Pennsylvania State College,
State College, Pa.

ONE of the present interesting cast materials is so-called pearlitic malleable cast iron. This group of irons combine some of the more advantageous features of gray cast iron, particularly resistance to certain types of wear, with a definite ductility which is lacking in the latter. Various details of the processing of such irons have been described in the ASTM *Symposium on Pearlitic Malleable Cast Iron.*[1]

Briefly, the starting point in manufacture is white cast iron of an analysis as will be indicated later. The structure of this raw material consists of pearlite and excess carbide, and by suitable heat treatment this is converted into a structure consisting essentially of lamellar or spheroidized pearlite plus graphite, the latter being in nodular or temper carbon form.

There are two possible methods of accomplishing this structural conversion:

1. By arresting the first stage of the malleablizing process above the A_1 temperature at the point where the excess iron carbide has been converted into temper carbon, and then by subsequent manipulation producing the desired decomposition product of austenite, or less commonly;

2. By complete malleableization to a structure of ferrite and temper carbon followed by reheating to such temperatures above A_1 that the austenite is caused to redissolve carbon and again produce the desired matrix by suitable regulation of the decomposition of austenite.

Admittedly there are various modifications of the possible methods described, and for a description of such, as well as details regarding temperatures, times and process, attention is directed to the aforementioned symposium.[1]

Since the structure of this material after malleableizing treatment consists of pearlite and nodular graphite, it is possible by heating to proper temperatures to convert this to a structure of austenite and nodular graphite.

By suitable regulation of the subsequent cooling rate and cooling conditions of this latter structure, it is possible to produce any of the transformation products of austenite, including the acicular products known as bainites, which have received much attention in the heat treatment of steel in recent years.

This investigation deals with two phases of the heat treatment of a typical pearlitic malleable iron. In one case the samples were subjected to a more or less common heat treatment consisting of oil quenching followed by tempering at various subcritical temperatures for various lengths of time.

The other heat treatment consisted of quenching samples to various subcritical temperatures below A_1 and holding at temperature to study the time of transformation of austenite and the hardness of the transformation product at various temperatures.

Such heat treatment has been termed isothermal transformation (transformation at constant temperature). Microscopic examinations were made of the structures developed as a consequence of such isothermal transformations.

Both of these heat treatments were in the nature of preliminary studies for possible future work involving

a comparison on pearlitic malleable iron of properties of quenched and tempered specimens with properties of isothermally transformed specimens of the same hardness.

Review of Literature

The investigations regarding the various phases of the heat treatment of steel have become so numerous that one can keep abreast of the developing and expanding picture best through the medium of the publications of various technical societies.

In recent years, similar attention has been fixed upon gray cast iron. Studies similar to those presented in this paper have been reported by Cohen and Hilliker,[2] Dowdell and Nagler,[3] Murphy and Wood,[4] and Flinn, Cohen and Chipman.[5] A summary of these and other investigations upon the subject of the heat treatment of gray cast iron has been presented by Hafsten.[6] Bartholomew[7] has described a practical application of isothermal transformation heat treatment to alloyed gray cast iron machine parts.

With specific reference to pearlitic malleable, Joseph[8] has discussed some of the phases of the heat treatment of this material in his many contributions to the subject. Cowan[9] has broached the subject of isothermal transformation heat treatment of pearlitic malleable cast iron and has presented photomicrographs of some of the transformation products.

In an interesting discussion of Cowan's paper, Walker[10] has suggested the use of isothermal transformation heat treatment as a means of accelerating spheroidization of pearlitic malleable, and has shown some results of such a heat treatment in the form of photomicrographs and a so-called "S" curve.

Experimental Technique

The material used for this investigation was received from the manufacturer in the form of tensile bars. The following analysis may be taken as typical of this iron:

Element	*Per Cent*
Carbon	2.55-2.65
Silicon	1.30-1.45
Manganese	0.42-0.47
Sulphur	0.11
Phosphorus	0.055

The microstructure in the iron as received and prior to any heat treatment by the authors is shown in Fig. 1.

Samples used for the heat treatment studies were cut from the tensile bars. All samples were cut to approximately the same thickness, namely, 0.15 in. The pieces used for the quench and temper runs were taken from the shoulders of the bars, and hence were ¾-in. diameter, while those used for the isothermal transformation runs were taken from the gage length portions where the diameter was ½ in.

Preliminary trials indicated that

Fig. 2—Martensitic structure in the iron resulting from an oil quench. Nital etch. 1000X.

the structure of austenite (plus nodular graphite), which is, of course, necessary for structural manipulation by subsequent adjustment of cooling rates and conditions, could be produced by holding the samples at a temperature of 1600° F. for 30 min. Consequently, this treatment constituted the first step in either of the two types of heat treatment.

Such heating was conducted in an open muffle electric furnace equipped with automatic temperature control. Precautions were taken to keep the samples off the floor of the muffle and to have the hot junction of the controlling thermocouple in close proximity to the samples. In all instances, the samples were introduced into the hot furnace already controlling at 1600° F.

Quench and Temper Treatment—All samples subjected to various tempering treatments were first quenched in oil from 1600° F. to ordinary or room temperature. Groups of such oil-quenched samples were then tempered at various temperatures, namely, 650, 750, 900, 1000, 1100 and 1200° F. A different group of samples was employed for each tempering temperature. The tempering times at each temperature were 15, 30, 45, 60, 120 and 240 minutes.

Tempering of the quenched samples was conducted in a bath of molten lead maintained at the desired temperature in each instance.

Isothermal Transformation Heat Treatment—The essence of this particular heat treatment is to cause austenite to decompose directly at various subcritical temperatures (i.e., temperatures below A_1 in the iron-carbon diagram) to transformation products characteristic of these temperatures.

Therefore, to accomplish this it is necessary that the sample be cooled from the austenitizing temperature to the subcritical temperature in question at such a rate that austenite will be the sole matrix constituent present originally in each and every sample brought to that particular subcritical temperature for study. Thus, it will be the decomposition

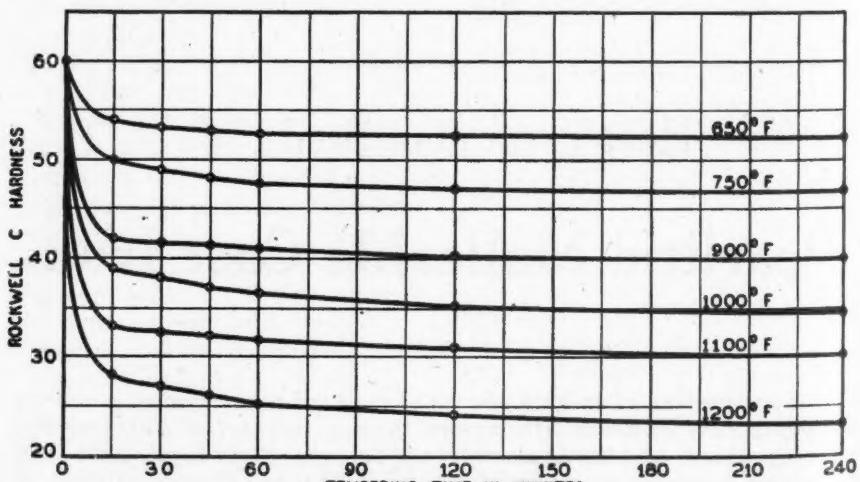


Fig. 3—Relationship of Rockwell C hardness to tempering time for each tempering temperature studied.

This paper was secured as part of the 1945 "Year-'Round Foundry Congress" and is sponsored by the Malleable Division of A.F.A.

of austenite at temperature which will be subjected to investigation.

Such requisites can be satisfied, as was done here by using relatively thin samples quenched from the austenitizing temperature into a bath of molten lead set to control at a specific temperature. In this way, the austenitic condition could be undercooled (below A_1) to certain temperatures by varying the temperature of the lead bath, and its transformation could be studied at these various temperatures.

Isothermal transformations were followed in this investigation at temperatures of 1200, 1100, 1000, 900 and 750° F. by the method to be described in a subsequent section.

Quenching and Tempering Runs—The results of this part of the study are much as would be expected. The samples as quenched in oil from 1600° F. possessed the matrix structure of martensite shown in Fig. 2. The hardness of such a structure was consistently Rockwell C 60 (± 1).

This martensitic structure and hardness is representative of the original condition of all oil-quenched samples subjected to tempering. The behavior of these quenched samples upon tempering at various temperatures is shown in the form of curves relating Rockwell C hardness to time of tempering in Fig. 3.

It is apparent that at each temperature the hardness of the quenched structure decreased rapidly in the first 15 min. and this was followed by further, more gradual softening over the remainder of the tempering period.

The well-known fact may also be noted from Fig. 3 that, the period of tempering being constant, the products of tempering are softer as tempering temperature is increased. This is more readily apparent from Fig. 4, wherein the decrease of hardness with increase of tempering temperature is plotted for a constant tempering period of one hour at each temperature.

This plot is approximately a straight line relationship over this range of temperature, namely, between 650 and 1200° F. This change in hardness correlates with changes in microstructure, as shown in Fig. 5. It can be noted that there is a progressive coalescence of the carbide with increase of tempering temperature up to the point where the specimen tempered at 1200° F. shows a rather definite spheroidized structure.

Isothermal Transformation Runs—The method used to follow the progress of the decomposition of austenite at various subcritical temperatures was the microscopic method originally suggested by Bain and Davenport.[11] The necessary technique for bringing structures of austenite (plus nodular graphite) to the subcritical temperature in question was described earlier in the paper.

Briefly, the microscopic method is conducted as follows: A batch of thin specimens is quenched from 1600° F., in this case, into the lead bath controlling at the desired

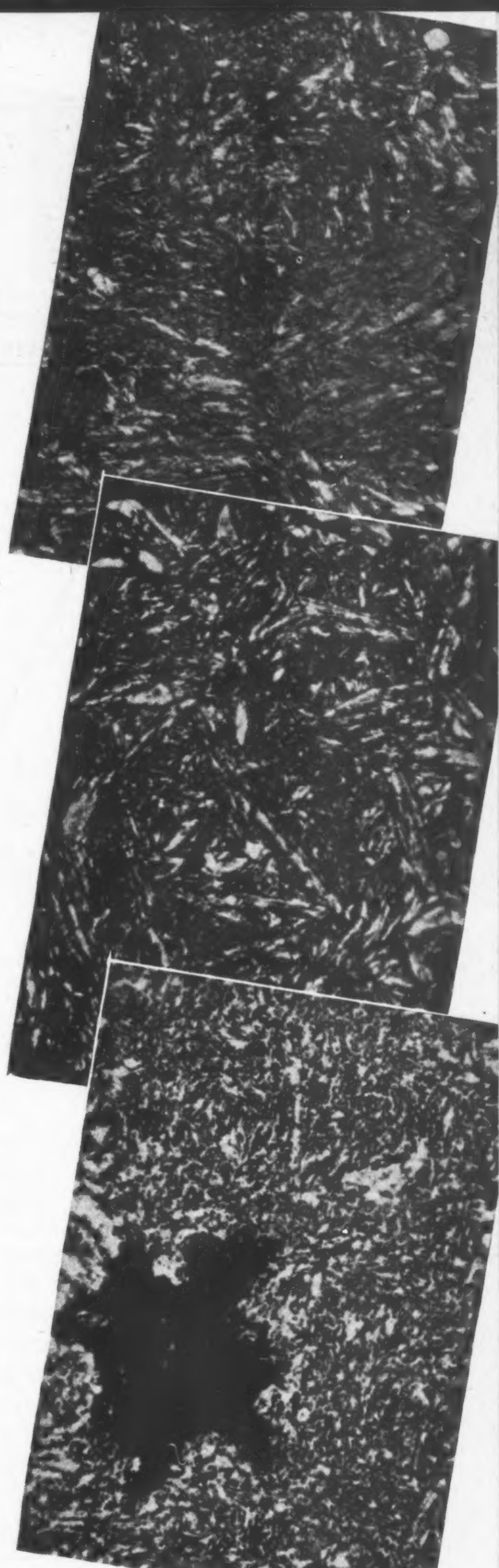


Fig. 5—Photomicrographs showing the structures produced by tempering oil-quenched samples for 1-hr. periods at temperatures (top) 750° F., (center) 1000° F., and (bottom) 1200° F. All 1000X.

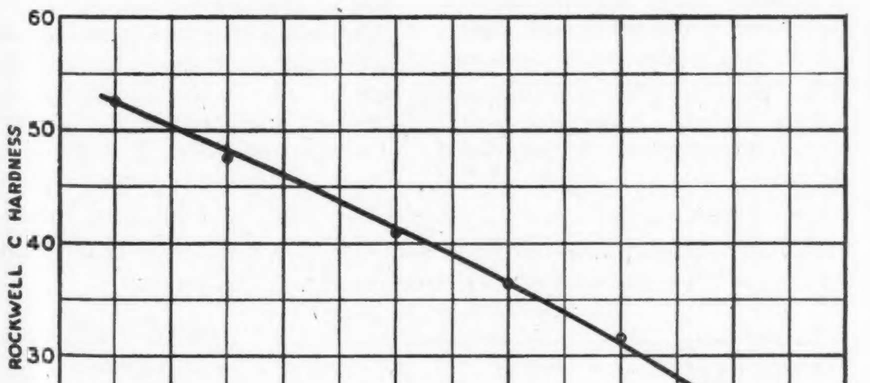


Fig. 4 (Left)—Progressive decrease of Rockwell C hardness with increase of tempering temperature. Samples were tempered for one hour in each instance.

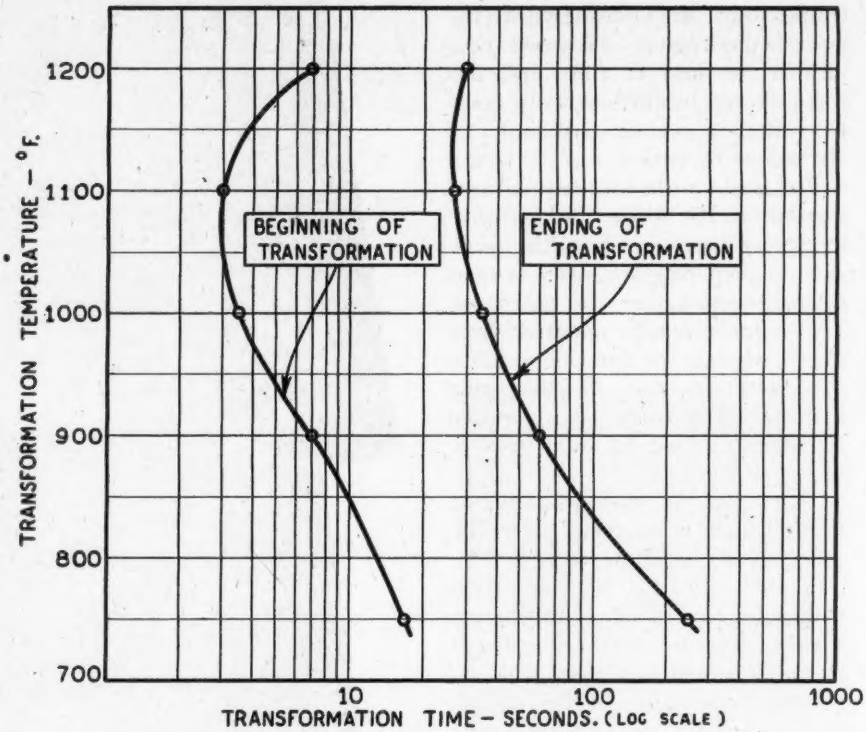


Fig. 6—Semi-logarithmic plot showing approximate beginning and ending of isothermal transformation at various subcritical temperatures.

temperature. Following a preselected time interval, one of the samples is removed from the bath and immediately quenched to the ordinary temperature in water. The sample is then examined microscopically.

It is known that austenite does not transform to martensite except at relatively low temperature (here in the water quench), and hence any martensite found in the microstructure will represent areas that were austenitic prior to the water quench or at the time the sample was removed from the subcritical lead bath. On the other hand, any product of transformation of austenite, such as pearlite or bainite, will be unaffected by the water quench.

This transformation product was present at the time the sample was removed from the lead bath and water quenched. Thus, if microscopic examination shows the sample to be 100 per cent martensite after water quenching from the lead bath, this means that the structure was 100 per cent austenitic at the time of removal of the sample from the lead bath. In other words, at that subcritical temperature (the temperature of the lead bath) the transformation of austenite had not commenced by the time the sample was removed and water quenched.

Any percentage of martensite less than 100 per cent in the microstructure would indicate the transformation of austenite in the lead bath to a lesser or greater degree. The amount of transformation can be estimated from the relative proportions of martensite and transformation product in the microstructure.

It is obvious that the requisites of this method, or any method, for studying the subcritical decomposition of austenite are:

1. The use of thin samples which are rapidly transferred from the austenitizing temperature to the subcritical temperature to insure that the sample as it initially comes to the latter temperature will rapidly attain that temperature as austenite.

2. The rapid cooling of the sample to ordinary temperatures once it is removed from the subcritical temperature being explored, so that the condition of the sample upon removal from this subcritical temperature is retained as much as possible (excepting, of course, that change from austenite to martensite in the water quench cannot be avoided).

Samples were quenched from 1600° F. to each of the subcritical transformation temperatures studied to determine the approximate beginning and ending of transformation at each temperature. In each instance, preliminary exploration was made at any temperature by quenching a group of samples into the lead bath and removing individual samples after 1, 5, 10, 100 and 1,000 seconds.

Additional samples were then quenched to and held at these temperatures in order to determine the beginning and ending times as was indicated to be necessary from the preliminary group.

The results of this stage of the investigation are summed up in Fig. 6 and the table. The time for the approximate beginning and ending of transformation at each temperature has been plotted (Fig. 6) in semi-logarithmic fashion and the results presented also in tabular fashion.

Transformation Products

The behavior of pearlitic malleable iron in these isothermal transformation heat treatments is further portrayed by the use of photomicrographs. These are presented in Fig. 7. One photomicrograph of the transformation product typical of each temperature is given, and it is to be noted that in each case a partially transformed sample was selected to better illustrate the nature of the product.

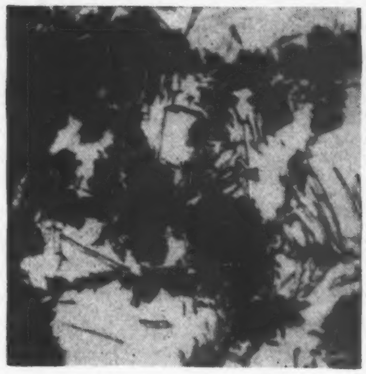
A consideration of these photomicrographs will show that at 1200 and 1100° F. the transformation product was pearlite, with that developed at 1200° F. being defi-

Tabular Data Concerning the Beginning and Ending of Isothermal Transformation at Each Temperature Studied

Transformation Temperature °F.	*Approx. Time (Seconds) for Transformation* — *To Begin*	*To End*	*Rockwell C Hardness at End of Transformation*
750	17	250	36-37
900	7	60	29-29
1000	3½	35	38-42
1100	3	27	35-37
1200	7	30	32-32

750° F.—100 sec.

900° F.—30 sec.



1000° F.—10 sec.

1100° F.—10 sec.

1200° F.—15 sec.

Fig. 7 — Photomicrographs illustrating the various structures developed by isothermal transformation at the indicated subcritical temperatures. Samples only partially transformed. All 1000X.

nitely more lamellar in appearance than that at 1100° F.

The structures developed at 900 and 750° F. are acicular or needle-like in appearance, the needles in the 900° F. sample appearing whitish and more coarse than those in the 750° F. sample, which etched dark. The sample transformed at 1000° F.* appears to consist principally of dark etching nodular pearlite, but a few traces of acicular product are evident.

An interesting feature is evident when the hardnesses of the samples which were approximately completely transformed are plotted against transformation temperature, as in Fig. 8. It is apparent that as transformation temperature is decreased from 1200 to 1000° F., the hardness of the nodular pearlitic transformation product increased progressively, as might be expected from the increasing fineness of the transformation product.

However, the acicular product formed by transformation at 900° F. was definitely softer, as indicated by the dip in the curve at this temperature. Further lowering of transformation temperature to 750° F. caused the acicular product to become definitely harder again, comparable with the hardness of the pearlitic transformation at 1100 or 1000° F.

Similar behavior has been found in the isothermal transformations of gray cast iron by Murphy and Wood,[4] as well as Hilliker and Cohen.[2] The latter investigators, by use of special etchants and x-ray analysis, attributed this hardness dip in the vicinity of 900° F. to the fact that the needles were ferritic in nature.

The increased hardness of the acicular structure formed at still lower temperatures was attributed to precipitation of a fine dispersion of carbide in the ferrite needles, which then etch darkly. This is to some extent confirmed by the etching reaction of the acicular structures in Fig. 7, although the present authors made no attempt to further investigate this point.

In summary, the following points are enumerated:

1. At a given temperature of tempering, the hardness of a quenched, martensitic structure will decrease rapidly in the initial stages of tempering to be followed by a more gradual decrease as tempering time is lengthened.

2. Increase in temperature employing a constant period of tempering results in a decrease of hardness

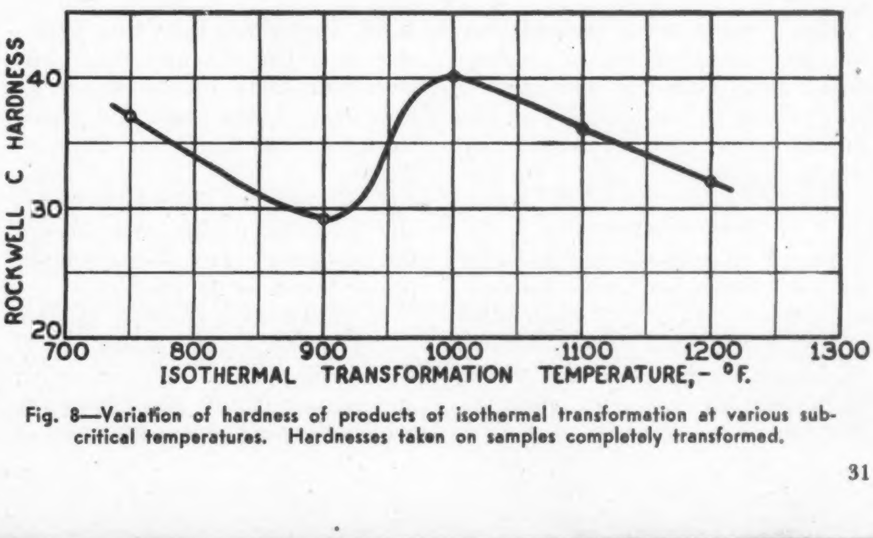


Fig. 8—Variation of hardness of products of isothermal transformation at various subcritical temperatures. Hardnesses taken on samples completely transformed.

in almost linear fashion. This is related to increasing coalescence of the carbide particles in the tempered structure with increase of temperature.

3. Isothermal transformation at temperatures from 1200° F. down to 1000° F. results in a nodular type of pearlite, which increases in fineness as transformation temperature decreases.

4. Isothermal transformation below 1000° F. produces acicular products which have been commonly referred to as bainites. The acicular product formed at 900° F. is softer than the nodular product formed at 1000° F. The hardness of these acicular products increased as transformation temperature was decreased to 750° F.

5. Data obtained as to the beginning and ending of transformation at the subcritical temperatures investigated indicate that transformation is initiated most rapidly at temperatures in the vicinity of 1000 to 1100° F. The time for beginning of transformation was between 2 and 5 seconds, and the transformation product was mainly nodular pearlite.

As a consequence of the present study, some interesting possibilities present themselves for further investigation. It is suggested that a comparison might be made of the properties of pearlitic malleable cast iron after isothermal transformation at various subcritical temperatures.

One important phase of such a comparison would be to determine, first of all, the maximum size of section which could be successfully transformed isothermally. A further extension would be to compare the properties of quenched and tempered structures with isothermally transformed structures of approximately the same hardness.

Such investigations might lead to the development of rather unexpected properties and further applications of this material, as has proved to be the case in steel in certain instances.

Acknowledgment

This is to acknowledge that this work was conducted at the Pennsylvania State College as a senior metallurgical thesis by J. E. Atherton, Jr., under the guidance and advice of R. W. Lindsay, then Assistant Professor of Metallurgy.

The authors extend their thanks to Carl F. Joseph, Research Metallurgist, Saginaw Malleable Iron Div., General Motors Corp., Saginaw, Mich., for supplying the iron used in this investigation.

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FOUNDRYMEN SCORE

In Annual Chicago-Mackinac Race

THE Chicago-Mackinac race, which is held annually, is probably one of the largest regattas staged on any of the Great Lakes. Each year finds schooners, yawls and Q boats setting out from the Windy City bound for the distant Michigan resort spot. Surprisingly, each year finds more and more A.F.A. members from the Milwaukee-Chicago area entering this race and running off with honors in the various classes.

Probably one of the "old timers" at trimming the mainsail and running up the jib is A.F.A. member A. M. Herrmann, Belle City Malleable Iron Co., Racine, Wis. Mr. Herrmann sailed on the 46-foot Q class sloop, Lively Lady, and placed second in the Universal Division, B class.

E. N. Wheeler, Belle City Malleable Iron Co., Racine, Wis., aboard the 50-foot Q class sloop, Spindle, placed fourth in the same class.

In the Cruising Division, D class, A.F.A. member Harry Bremer, H. E. Bremer Mfg. Co., Milwaukee, owner and skipper of the sloop Rangoon, achieved second place. Members of his crew included National Director George Dreher, Ampco Metal, Inc., Milwaukee. The sailing bug which has bitten so many foundrymen can be well explained by the words of Mr. Dreher. When asked how he liked the race and if he would go again replied:

"I'll certainly go again."

Technical Aid Given Through TDP Library

A LETTER recently received by the National Office highly praised the TDP library and the cooperation given the writer while doing some research work on a particular phase of foundry operation. The letter stated, "It is certainly nice to know that there is a source close to us where we can obtain authoritative information on various phases of our business."

The Association is proud that its library is contributing much to the foundry industry.

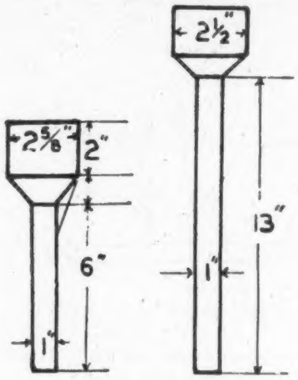
Cause and Control of Magnesium Alloy Microporosity

• The twenty-fourth in an unbroken series of annual exchange papers — 1922-1945 — from the Institute of British Foundrymen to the American Foundrymen's Association . . . treatment in the present paper of cause and control of microporosity in magnesium alloys attests the value of this broad exchange of knowledge and ideas for the common advancement of the foundry industry.

**By E. A. G. Liddiard,
Research Manager,
and
W. A. Baker, Investigator,
British Non-Ferrous Metals
Research Association,
London, England**

Fig. 1A—(left) D.T.D. bar. Poured inclined 30° to vertical and left in that position.

Fig. 1B—(right) Top run bar with feeder usually too small to give complete feeding. Cast in inclined position.



THE FORM and distribution of porosity in magnesium base alloy castings solidified under controlled conditions have been studied and some comparative tests made on aluminum-base alloys of similar constitution. It is concluded that:

1. The characteristic microporosity in magnesium alloys is due essentially to unfed shrinkage in alloys which solidify over a temperature range.

2. That the presence of gas in magnesium-base alloys causes a marked increase in the amount of microporosity in the casting and does not alter its characteristic form.

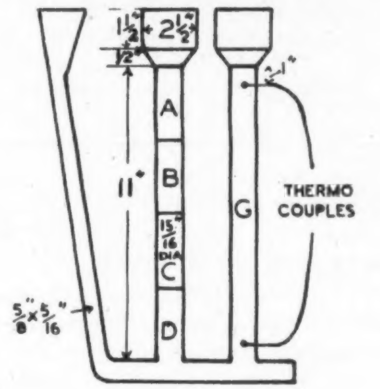
3. That owing to their low heat capacity and relatively rapid solidification the temperature distribution in many magnesium-alloy castings tends to be less favorable to progressive feeding.

4. That under the same solidification conditions the strength of unfed castings in magnesium and aluminum alloys is affected to the same extent, but that it is more difficult to ensure correct solidification conditions in magnesium than in aluminum alloys.

Foundry technique must be such that the metal is free from gas initially and does not pick up gas by reaction with overheated sand. Running, pouring and gating conditions must be adjusted to ensure progressive solidification from the important parts of the casting toward the risers and feeders.

One of the principal difficulties encountered in making castings in magnesium alloys is the occurrence of a fine form of porosity known as microporosity, and the British Non-Ferrous Metals Research Association

Fig. 1C—Bottom-run vertical bar. Round-section parallel bars, top-fed, showing location of couples and position of A, B, C, D, G bars. Similar bars were made without feeders but with 1 in. dia. downgate and runner and poured at controlled rate through a bush.



has carried out an extensive research to determine the causes and methods of controlling microporosity in magnesium alloy castings. The following paper gives an outline of the results so far obtained. More complete details of the experimental work are given in a paper by W. A. Baker, which has been submitted to the *Journal* of the Institute of Metals.

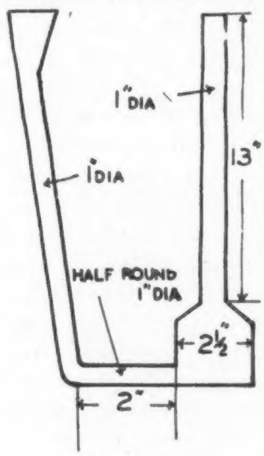
I. General Lines of Investigation

The investigation has been mainly concerned with sand castings. Castings have been made in various alloys of magnesium, using test castings of different forms. The broad lines of investigation are dealt with as follows:

1. *Metals Used.* All alloys were prepared from pure commercial materials including 99.8 per cent purity magnesium, 99.99+ per cent or 99.5 per cent purity aluminum, 99.99+ purity zinc, 99.8 per cent purity nickel (pellets). Where other constituents were added, these were also of the highest purity obtainable.

2. *Melting.* Alloys were melted in iron crucibles, covered during melting with flux Z, and refined by stirring at a temperature of 1292-1382° F. (700-750° C.) with flux E. Except where otherwise stated, the alloys were superheated to a temperature of 482° F. (250° C.) above the liquidus temperature, i. e., to about 1562-1652° F. (850 to 900° C.) for most alloys. During the superheating the alloys were protected with flux E. Gas-fired melting furnaces

Fig. 1D—Bottom-run bottom-fed bar poured at controlled rate through a bush.



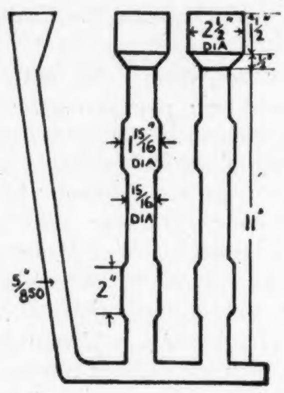


Fig. 1E—Bottom-run round or square-section bulged bars. Similar bars were made with no feeder at top but a 1 in. square downgate, and poured through a bush.

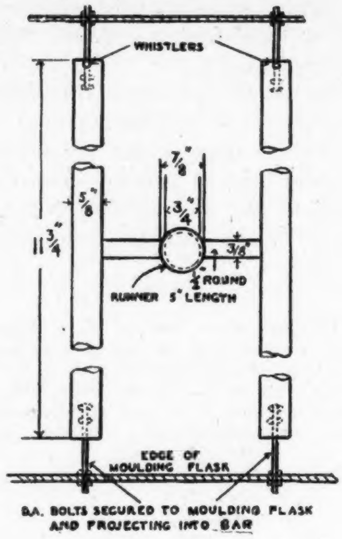


Fig. 1F—Hot-tear test casting.

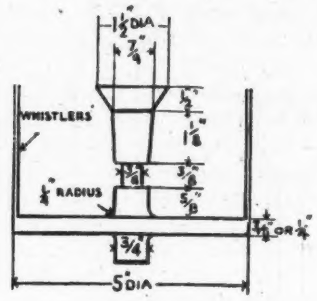


Fig. 1G—Pressure-disk casting. Restricted feeding into boss.

were used for most of the melting work done in this investigation.

3. *Mold Materials.* Unless otherwise stated the alloys were cast in a highly permeable silica sand mixture containing 6 per cent of sulphur, 0.5 per cent of boric acid, 4 per cent of bentonite or 5 per cent of no. 1 (a fuller's earth essentially calcium montmorilbonite similar in some respects to American bentonite).

4. *Types of Castings Used.* Several different castings were used; the main types are illustrated in Fig. 1, although some alterations were made in the dimensions during the work.

(a) D.T.D. type bars which in general gave specimens free from porosity and whose properties formed a standard for comparison purposes. This is the form of test bar normally specified in Britain by the Directorate of Technical Development of the British Ministry of Aircraft Production.

(b) A top-run bar with feeder of varying size generally too small to give complete feeding.

(c) A bottom-run vertical bar with a feeder head at the top, termed a conventional bar.

(d) A bottom-run, bottom-fed bar, termed an inverted bar.

(e) A bottom-run bulged bar of either circular or rectangular cross-section, with or without a feeder head at the top.

(f) A hot-tear test casting in which horizontally cast bars were cast around small insert bolts, which were secured to the molding flask by means of a nut. The nut could be slackened back to vary the degree of restraint applied to the bar during solidification.

(g) A pressure-disk casting. A flat disk with a central boss tested up to 200 psi. air pressure in machined and unmachined condition.

Except for the D.T.D. bar, all of the foregoing castings were not fully fed, and were designed for study of the effects of varying distribution of shrinkage porosity. A few castings were also made in chill molds, which were lowered into molten lead-tin alloys held at a controlled temperature.

5. *Methods of Examination.* The castings produced were examined in the following ways:

(a) Density. The densities of the castings or sections cut from castings were determined, from which the proportion of voids in the metal could be calculated. The specific gravity of a casting that had not been properly fed was compared with that of a D.T.D. bar. That the D.T.D. bars usually gave the maximum density of the alloys was proved by microscopic examination, which showed them to be free from porosity, and by the fact that the densities were the same as those of sound chill-cast blocks.

(b) Mechanical Tests. Test pieces were cut from various parts of the castings and tested in tension to show the effect of a given amount of porosity on the strength of the material. The strengths were expressed as percentages of those of sound D.T.D. bars poured from the same melt.

(c) X-Ray Examination. Most of the castings were radiographed, from which the occurrence of streaks of porosity, or localized patches of porosity, could be seen.

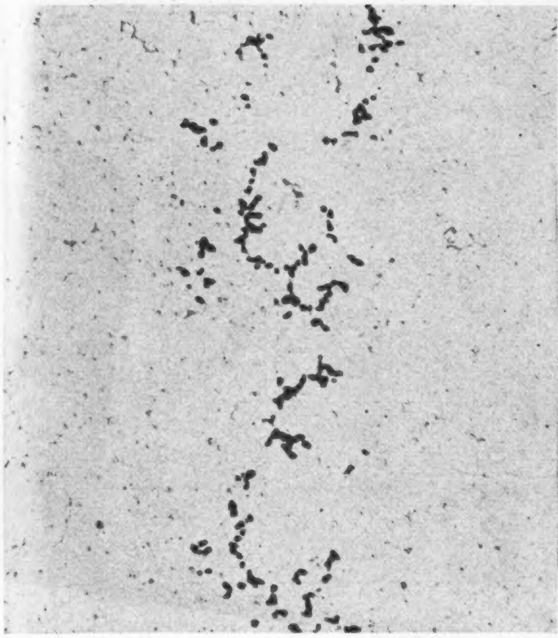
(d) Micrographic Examination. Microsections were prepared from various portions of the casting.

FLUX COMPOSITION*

	Per Cent Flux Z	Per Cent Flux E
$MgCl_2$	11	34
$CaCl_2$	42	15
NaCl	27	9.5
KCl	18	7
MgO	—	10.5
CaF_2	—	18

*British Patents Nos. 539023, 561748, 539024, 562597 and 562636 may be consulted for the compositional range of these fluxes.

Written discussions of this paper are solicited for publication in future issues of "American Foundryman" and/or bound volume of "Transactions." Discussions should be sent to Secretary, A.F.A., 222 West Adams St., Chicago 6, Ill.



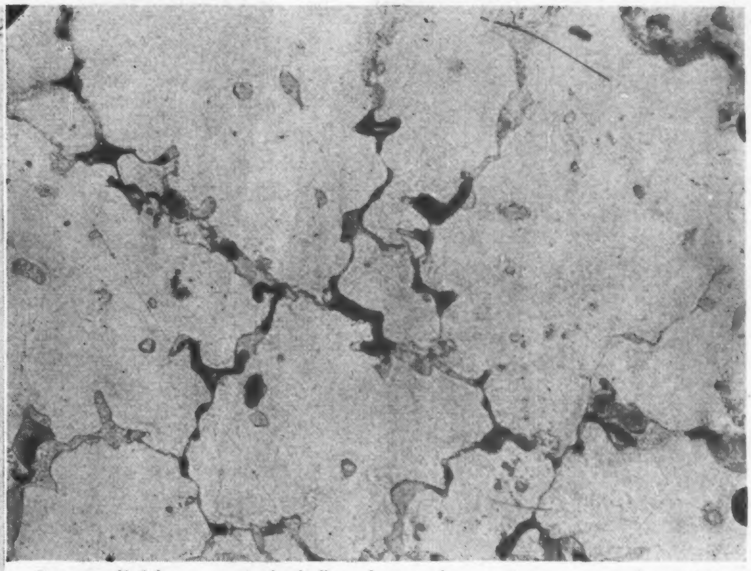


Fig. 2—(left) A typical shallow layer of porosity in a sand casting (partially solution heat treated 93/7 Mg-Al). 40X. Fig. 3—(above) Showing interdendritic fissures. 250X.

These served to show the form and distribution of porosity.

II. Porosity Form and Distribution

The form of porosity met with in magnesium-base alloys differs in certain respects from that normally found in other cast metals, and the following terms are used throughout this paper to define particular types of porosity.

1. *Microporosity.* This means finely distributed porosity occurring around the grain boundaries. Typical examples are shown in Figs. 2 and 3. This intercrystalline porosity is not, however, peculiar to magnesium-base alloys, although, since most magnesium alloys are finer grained than other cast materials, e. g., aluminum-base alloys, the porosity is finer. As in many other nonferrous alloys, intergranular or microporosity is shown up as discolorations on fractured castings. It is most pronounced on alloys fractured after heat treatment, the color varying from light straw to almost black.

2. *Layer Porosity.* A particular form of porosity, peculiar to magnesium alloys, shows up on radiographs as dark streaks in sand castings (Fig. 4). Under the microscope these streaks show up as strings of porosity, as shown in Fig. 5. For want of a better description, this type of porosity has been called layer porosity throughout the work, and means porosity appearing as small intercrystalline cavities in patches shallow in depth and of relatively large area.

The layers are at right angles to the wall of sand castings. X-rays only reveal this porosity when the layers lie in the same plane as the x-ray beams. That is one of the reasons why in practice it is necessary to take a large number of x-ray shots in different directions, to be certain that any casting is free from layer porosity.

3. *Intense Concentrations of Porosity.* A patch of porosity is often concentrated at one part of a casting. This form of porosity is common to most cast alloys, and it has the most serious effect on strength. In a radiograph it shows up as a formless mass of porosity, and is independent of the direction of the x-ray beam. Fig. 6 is a photomicrograph showing an intense concentration of porosity in a magnesium alloy. It commonly occurs in that part of an unfed casting which is the last to solidify.

4. *Secondary Pipe.* This takes the form of a single cavity situated at the last part of the casting to solidify. It is found in materials which solidify with little or no freezing range, i. e., pure metals and eutectic alloys. A typical example of a secondary pipe in a eutectic aluminum-magnesium alloy is shown by the photograph in Fig. 7.

5. *Annular Porosity.* This is a defect which appears to be much more pronounced in magnesium-base alloys than in others. It appears in cylindrical chill castings in which an annulus of porosity is found at a distance from the chill face. The external skin of the chill casting is perfectly sound and the internal portion is relatively sound. In many cases the annulus of porosity is resolved into a large number of adjacent small layers normal to the mold wall. A similar type of porosity is

Fig. 4—Layer porosity shown by x-rays.

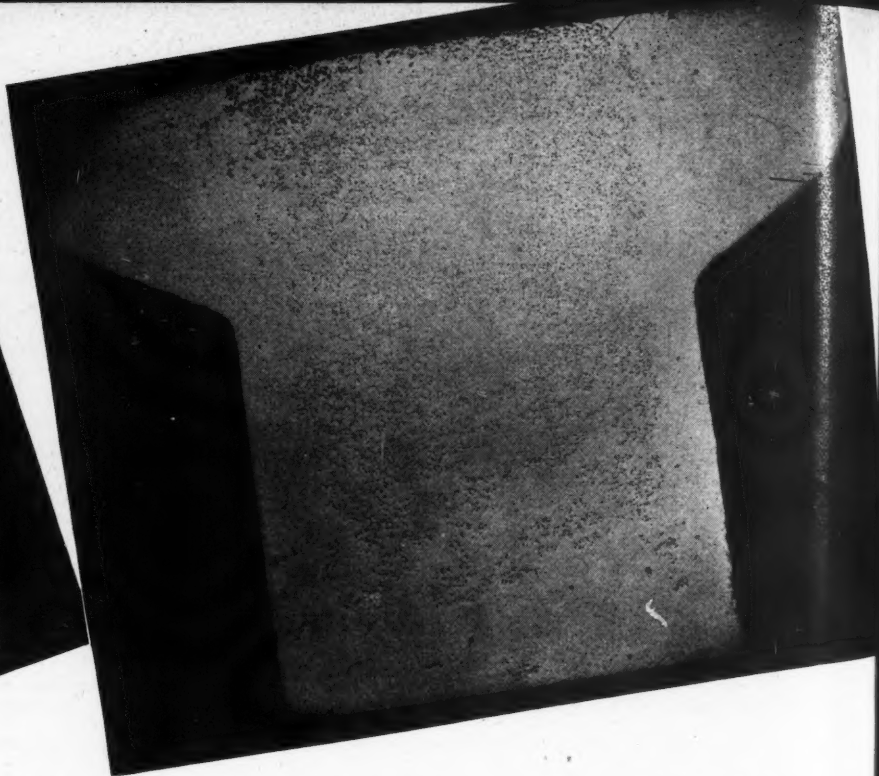


Fig. 5—(left) Layers of porosity in a moderately unsound casting. 2.5X. Fig. 6—(above) Intense concentration of porosity in a badly fed sand casting. 2.5X.

also seen in sand castings poured at low temperatures.

III. Effect of Gas

When gas is given off from a metal during solidification, a portion of it is almost invariably trapped inside the casting, where it forms cavities. When the gas comes off while most of the metal is still liquid, the cavities tend to be spheroidal, since the pressure of the gas is greater than that of the atmosphere and the head of still liquid metal, but if most of the metal has solidified before the gas comes off, it will force the still liquid metal from between dendrites that have solidified.

In the complete absence of gas a shrinkage cavity would be a vacuum, and hence even the smallest amount of gas allows cavities to form more easily as a result of the shrinkage of the solidifying metal. It follows that there is no sharp distinction between gas and shrinkage cavities, and it is impossible by merely looking at a cavity between the grains of a metal to say to what extent gas has played a part in its formation.

However, if the metal is allowed to solidify under reduced pressure, the effects of gas are exaggerated and one can estimate whether it is likely to play an important part in a casting solidifying under normal atmospheric pressure.

The possibility that porosity in magnesium-base alloys might be mainly due to gas given off from the metal was one of the first points to be investigated. An outline of the experimental work on this subject follows.

1. *Test for the Presence of Gas.* The test used in this work is illustrated in Fig. 8. A sample of the molten metal is scooped out of the pot into a small, thin-walled iron crucible, which is held in molten metal long enough to reach the same temperature as the melt. The crucible is then transferred to a vessel (with a glass window for observation) which is connected to a large reservoir, which has previously been pumped out to a low pressure.

On connecting the evacuated reservoir with the vessel in which the crucible is placed, the pressure falls to about 60 mm. of mercury. The metal is carefully observed during solidification, and when the sample has solidified it is cut up and examined if necessary. If the metal contains gas, bubbles of gas can be seen rising to the surface while the metal solidifies, and the small ingot, when solid, shows blowholes, as illustrated in Fig. 9.

2. *Experimental Work.* The appropriate gas was bubbled through the molten metal for varying periods before casting. Some tests were made using sulphur dioxide, carbon dioxide and carbon monoxide, but most of the work was done with hydrogen. A magnesium-7 per cent aluminum alloy was used, and the following test castings made:

D.T.D. bars (Fig. 1 A), including some with 1½ in. diameter head.

Up-run bars but without a feeder head, and with runner 11 in. long and of 1-in. diameter (Fig. 1 C).

3. *Results.* No gas unsoundness

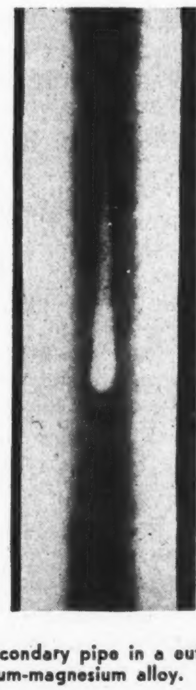


Fig. 7—Secondary pipe in a eutectic aluminum-magnesium alloy. 1X.

was found after treatment with sulphur dioxide, carbon dioxide and carbon monoxide, although considerable drossing occurred on treatment with the oxides of carbon.

Melts made from virgin materials or from scrap which had been in storage for only a short time under reasonably good storage conditions gave only slightly gassy melts. Metal which had been in storage for some time, particularly that which had corroded, was gassy, but gas could be driven off by heating the metal to a temperature of about 680° F. (350° C.) for 16 hr. before melting, and could also be removed by allowing the molten metal to solidify, whereupon all the gas was given off, and then remelting.

This procedure, well known in ordinary foundry practice, is known as presolidification. Gas could also be removed by chlorine treatment. However, it was found that some porosity developed in the castings made in the top-poured bars with small heads and in up-run 11-in. bars, even when the melt was shown by the test previously described to be substantially free from gas, but no porosity was found in gas-free metal cast in D.T.D. bars (Fig. 1A).

Hydrogen Porosity

When hydrogen was introduced into the metal before casting some porosity was found in the D.T.D. bars, and the amount of porosity in the other bars increased with a corresponding decrease in strength. As more hydrogen was introduced into the metal, so the amount of porosity in all the bars increased and the strength decreased. However, the form of the porosity was not altered by the presence of gas.

4. *Possible Gas Pick-Up from the Mold.* The foregoing tests were carried out on the assumption that the only gas given off on solidification would be that gas dissolved in the molten metal before casting. However, recent work by the association has shown that many non-ferrous metals pick up hydrogen by reaction with moisture present in sand molds, and even metal which before casting was shown to be free from gas sometimes gave porous sand castings.

A few tests were made to see if magnesium-base alloys picked up gas from molds. Some castings were made in the normal sand mixture, some using Red Mansfield sands (a naturally bonded fine sand containing 4 to 5 per cent of water and with relatively low permeability, e. g., 20 to 30 A.F.A.), uninhibited and partially dried by heating for an hour at 212° F. (100° C.), and others in Red Mansfield sand, uninhibited but thoroughly baked at 1652° F. (900° C.). (This high-temperature baking had been found necessary in other work to eliminate gas pick-up with phosphor bronze.)*

The metal burnt in the partially dried Mansfield sand, and a great deal of porosity, which was of the usual layer form, was found in the bars. However, no porosity was found in bars cast in the inhibited green sand or in the Mansfield sand baked at 1652° F. (900° C.), although in the latter there was considerable penetration of the metal into the sand.

These tests showed that magnesium-base alloys can absorb gas from wet sand molds, although the presence of sulphur in the sand appeared to be sufficient to prevent appreciable gas pick-up. However, even in inhibited molds it is possible that some gas pick-up may occur by reaction between the metal and moisture in the mold, particularly in overheated parts. Fractures through runners and ingates are often badly discolored in the outer layers, suggesting some reaction with the mold atmosphere.

5. *Conclusions.* 1. Gas is not the primary cause of porosity in magnesium castings, since porosity has been found to develop in material which has been tested and shown to be free from gas liable to be evolved on solidification and when precautions were taken to avoid regassing in the mold.

2. The presence of gas in magnesium-base alloys causes a marked increase in the amount of microporosity in the casting and does not alter its characteristic form, i. e., layers of porosity in sand castings.

3. Gas in magnesium alloys may arise in practice from corroded metal. It is assumed that the corrosion products carry with them considerable quantities of moisture which reacts with the metal when molten, introducing hydrogen. The danger can be minimized by storing ingot metal and scrap under dry conditions, or by heating the metal long enough to dry the moisture from its surface before charging.

4. Gas can be easily removed by presolidification, i. e., by allowing the metal to solidify and remelting.

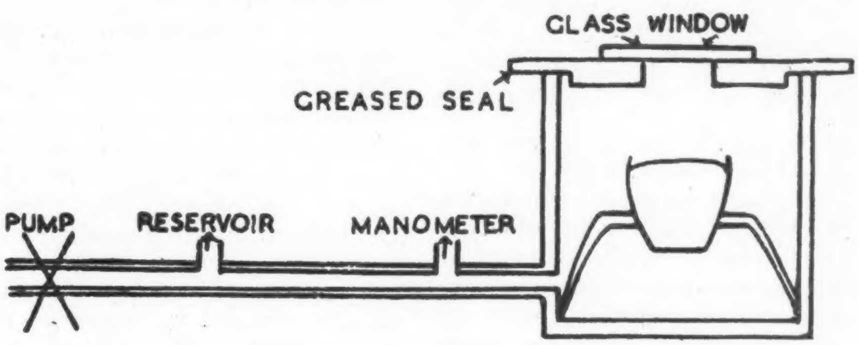


Fig. 8—Illustration of the test for the presence of gas.

IV. Effect of Alloy Constitution

It is well known in the trade that certain magnesium alloys are more prone to microporosity than others. This is not surprising, since it is well known that the form and amount of porosity in other non-ferrous metal castings depend on their constitution. One of the most important factors governing distribution of porosity is the freezing range of the metal, i. e., the temperature range through which the alloy solidifies.

Pure metal and eutectic alloys have no freezing range, but most alloys solidify over an appreciable temperature range. In a simple al-

*W. A. Baker, F. C. Child and W. H. Glaisher, "The Effect of Shrinkage and Gas Porosity on the Pressure Tightness and Mechanical Properties of Bronze Sand Castings," *Journal,* Institute of Metals, vol. 70, pp. 373-406 (1944).

loy system, such as aluminum-magnesium, the freezing range can be altered by altering the proportions of the two alloying constituents.

In addition to the freezing range of the material the relative proportion of the metal which solidifies at different temperatures is important. For instance, in some alloys nearly all of the metal solidifies at quite a high temperature and a small amount of liquid remains at the end, and does not solidify until at a much lower temperature.

In other alloys a large proportion solidifies at the lowest temperature. In general, the way in which an alloy solidifies determines the form and distribution of the shrinkage porosity, which is bound to occur unless the casting is completely fed.

1. *Experimental Work.* To study the effect of constitutional change the magnesium-aluminum system was used, and alloys were made containing 2.5, 5, 10, 20 and 32 per cent of aluminum, with freezing ranges varying from 392° F. (200° C.) to 32° F. (0° C.).

Freezing Ranges

It should be kept in mind that the freezing ranges of the alloys are not necessarily those given by the equilibrium diagram, since solidification in a sand casting does not take place under equilibrium conditions.

In this work some of the alloy melts were not superheated, so that a comparison was made between castings with different grain size. However, it should be noted that even in the castings described as coarse-grained the grain size was smaller than that normally found in most other commercial casting alloys, including aluminum alloys.

Test bars used included D.T.D. bars (Fig 1 A), up-run bars 12 in. long (Fig. 1 C), disk castings (Fig. 1 G) and hot-tear tests (Fig. 1 F).

2. *Results.* The results obtained showed that the amount of porosity, as judged by density measurements, did not vary much with the constitution of the alloy, and that microporosity was liable to develop in any magnesium-base alloy which solidifies over an appreciable freezing range and which is not properly fed.

X-ray examination showed typical layers of porosity in both the fine and coarser-grained castings, but the eutectic alloy in each case showed secondary pipe with no layers of porosity. In the 20 per cent alloy also, the porosity tended to concentrate in the center and was intermediate between typical layer porosity shown by the other alloys and the secondary pipe shown by the eutectic alloy.

Properties of Alloys

The eutectic alloy was extremely brittle, and the tensile properties of the 20 per cent alloy were, in general, rather poor. However, there was little to choose between the properties of the other alloys in the coarser-grained castings, but in the fine-grained superheated castings the maximum tensile strength was obtained with the 5 per cent alloy, and in each case was higher than the corresponding strength with the coarser-grained material. This applied both to the D.T.D. bars and the up-run bar.

None of the fine-grained disk castings leaked in the unmachined condition, although some leaked on machining. However, the pressure disks made in the coarse-grained material were much more liable to leak, and in some cases showed cracks around the boss. The finer-grained castings usually showed surface shrinks rather than cracks. The behavior in the pressure-disk test was explained by the results from the hot-tear test, which showed more failures in the coarser than in the fine-grained material.

With a fine-grained material the surface of the casting during solidification consists of a large number of very small crystals suspended in a liquid, and this tends to collapse as a whole as the casting shrinks. However, with a coarser-grained material there is a greater tendency for cracks to form between the grains while the material is solidifying, because the larger crystals rapidly form a coherent mass which cannot collapse as a whole.

Grain Size Effect

Poor resistance to pressure tightness and to hot tearing to some extent therefore go hand in hand, and are controlled, at least in part, by the grain size of the casting. With comparable grain size, the alloys of low aluminum content (e.g., 2.5 and 5 per cent) were more prone to hot-tear and to give defective disk castings than those of higher aluminum content (e. g., 10 and 20 per cent), and this can be explained on similar lines.

In alloys of low aluminum content, most of the metal freezes in the upper part of the freezing range and the interlocking crystals formed are surrounded by thin films of low-melting-point metal. The contraction of the primary crystals during cooling in the lower part of the freezing range tends to pull them apart and produce hot tears, the intercrystalline films of liquid having negligible strength.

In alloys of higher aluminum content, there is a relatively large proportion of liquid metal remaining liquid down to the solidus temperature, and the contraction of the primary crystals is accommodated by feeding of this eutectic liquid or, in some cases, by feeding of the whole mass of small primaries and eutectic.

V. Mode of Solidification of Magnesium and Aluminum-Base Alloys

The work described in the following paragraphs was carried out in an endeavor to correlate the manner in which magnesium alloys solidify with the types of porosity found in them. At this stage it is worth while pointing out some essential differences between magnesium and other non-ferrous metals. Magnesium is by far the lightest of the commercially used metals, aluminum being the next. Magnesium differs from other commercial used metals, except zinc, in crystallizing in the hexagonal system; most other metals are cubic.

Another striking difference between magnesium and most other non-ferrous metals is in the low heat capacity of magnesium. Much less heat is required to melt a given volume of magnesium than for any other metal because of the low specific heat and latent heat per unit volume. Magnesium will therefore solidify much more quickly than any other commercial metal when cast into the same type of mold. Figures showing the density and thermal properties per unit volume of magnesium as compared with other metals are given in Table 1.

1. *Alloys Tested and Types of Castings Used.* A large variety of alloys were tested, including aluminum-base alloys as well as magnesium-base alloys. The alloys were chosen to have similar constitution

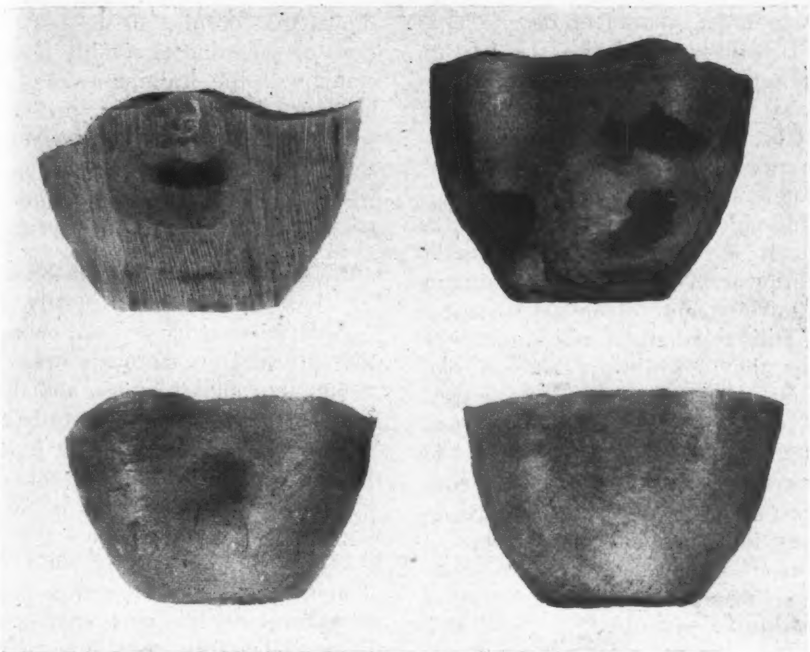


Fig. 9—Examples of ingots solidified under reduced pressure. IX.

and freezing range. All the types of castings described in the introductory section were used.

2. *Methods of Modifying Solidification Rates.* As already indicated, magnesium-base alloys will, under comparable conditions of cooling, solidify much more rapidly than aluminum-base alloys. It became necessary therefore to find out what part this relatively rapid solidification rate played in determining the distribution of porosity.

Castings of similar form in both magnesium and aluminum-base alloys were therefore cast in such a way as to give comparable solidification rates. For example, the rate of solidification of a metal can be delayed by using a high casting temperature. This results in excessive heat being introduced into the metal in the mold, and consequently the casting takes longer to solidify.

One method used to lower the solidification rate of magnesium-base alloys was to use a high casting temperature. However, a small amount of calcium was added to prevent burning in alloys cast at high temperature, preliminary tests having shown that calcium additions had no significant effect in solidification behavior or porosity.

Another method adopted was to preheat the mold before casting. This slowed down the rate at which heat was taken away from the metal by the mold and again resulted in a slower rate of solidification. The solidification rate of aluminum-base alloys was increased by introducing uniformly spaced chills into the mold.

3. *Measurement of Temperature Gradient during Solidification.* In some of the test castings made, particularly those of vertical up-run bars (Fig. 1 C), thermocouples were placed at the top and bottom of the castings and records were taken of the temperature during their solidification. From these records curves were drawn showing temperature changes with time.

In most cases it was found that the temperature at the top of the bar was lower than at the bottom when the mold was first filled. However, as the metal solidified, the temperature difference between the top and bottom altered, and Figs. 10 and 11 are typical examples of the type of curve obtained.

When the temperature at the top of the casting was lower than at the bottom, as in the early stages of solidification of the casting to which Fig. 10 refers, solidification would proceed more rapidly at the top. In this case the feeder head was at the top, and during the early stages of solidification feeding from the feeder head downward would be hindered.

The ideal temperature distribution would be that the top of the casting near the feeder was always hotter than the lower part, so that feeding proceeded downward while solidification progresses upward. By comparing the areas "ABC" in Fig. 10 with the area "CDE," one can obtain an indication of the amount by which the temperature gradients during solidification of the casting were unfavorable.

In the example given in Fig. 10 area "ABC" is about one-third of that of "CDE," and the strength of the casting was only 50 per cent of that of a fully fed D.T.D. bar. In the casting to which Fig. 11 refers the temperature gradients were favorable during almost all of the time that the casting was solidifying. In this case the strength of the casting was 84 per cent of that of a fully fed D.T.D. bar.

4. *Mechanical Tests.* Test pieces were cut from various sections (A, B, C and D) of the bar, as indicated in Fig. 1C, and also on a complete bar (G). Density determinations were also made on the various sections of the bar.

5. *Results.* The total amount of porosity found in aluminum alloys, judged by density, was in every case more than that found in magnesium alloys under similar solidification conditions. The tensile strengths of castings which were not fully fed were about the same in both magnesium- and aluminum-base alloys, provided that the conditions of solidification were similar. For a given amount of porosity, as judged by density measurements, the effect on the strength of magnesium alloys

Table 1

THERMAL PROPERTIES PER UNIT VOLUME OF MAGNESIUM COMPARED WITH OTHER METALS

Metal	*Specific Gravity*	*Mean Specific Heat cal./cm.^{3}/° C.* Solid	Liquid	*Latent Heat of Fusion*
Magnesium	1.8	0.50	0.54	90
Aluminum	2.7	0.68	0.70	250
Copper	8.9	0.89	1.06	440
Iron	7.8	1.25	1.34	500

was greater than for aluminum alloys.

When bars in aluminum- and magnesium-base alloys were cast in green sand molds of the same dimensions, it was found that the unfavorable heat distribution during solidification was very much greater in the case of magnesium alloys than in aluminum alloys, but when conditions of cooling were adjusted (either by preheating the mold or casting at a higher temperature for magnesium alloys, or introducing chills into the sand for the aluminum alloys), the relative strength of the two materials was approximately the same.

By relative strength is meant the strength in the unfed casting as a percentage of the strength of fully fed D.T.D. bars. Typical figures are given in Table 2, which includes a column headed "solidification factor," which is derived from curves as illustrated in Figs. 10 and 11.

A high solidification factor means that during the major part of solidification the temperature gradients were favorable. The solidification factor is actually derived from the ratio of the amount of solidification that took place under a favorable temperature gradient to that taking place under an unfavorable gradient.

It will be seen that the loss in strength in the unfed castings depends essentially on the solidification factor, and that there is no real difference between aluminum and magnesium alloys in this respect. This point is illustrated in Fig. 12, which shows the relation between solidification factor and minimum relative strength of up-run bars.

This relation is independent of the alloy. However, there is one point on which a difference persists. In the unfed magnesium-alloy castings, the porosity takes the form of layers of porosity or of intense concentrations of porosity; whereas in the aluminum alloys no layers of porosity were detected by x-rays, although intense concentrations of porosity were found.

The most important conclusion from this work is that, owing to their low heat capacity, magnesium alloys solidify relatively fast in green sand molds, and that the temperature conditions tend to be less favorable to progressive feeding. Greater provision must therefore be made for feeding these alloys than for most other non-ferrous metals.

In other work of the Association on inverse segregation it has been shown that porosity in the last portions of a casting to solidify is associated with the draining away of the last portions of liquid. Experiments were made to determine whether there was a deficiency of the liquid which was last to solidify in porous parts of magnesium alloy castings.

VI. Miscellaneous Experiments on Layer and Annular Porosity

Analyses were carried out on samples drilled from porous patches in magnesium alloy castings, and these porous patches were found to be deficient in the last solidifying liquid. In binary aluminum - magnesium alloys the last remaining liquid is higher in aluminum than the remainder of the casting, and the analysis of the porous region shows deficiency in aluminum content. It follows, therefore, that some of the liquid has drained away during the last stages of solidification.

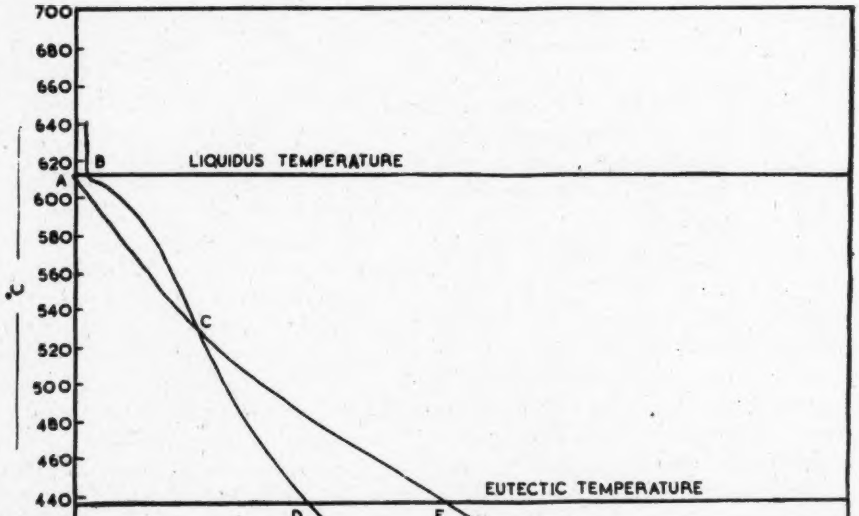
This was further proved by adding a small amount of copper to the alloy, since this copper is also associated with the last portions of the alloy to solidify. Again, a deficiency in copper was found in the porous regions. In this respect also, therefore, magnesium alloys behave similarly to other alloys.

Some castings were also made in magnesium-base alloys to which beryllium was added. Beryllium has the effect of increasing the grain size considerably until it approximates that of a coarse-grained aluminum casting with grain dimensions of the order of 3-4 mm., as compared with about 0.1 mm. for beryllium-free metal.

In these alloys a striking change was observed in the distribution of porosity, which tended to concentrate toward the center of the casting, the patches of porosity having roughly equal dimensions in three directions at right angles, with no layers of porosity such as were found in castings of the same form in a fine-grained material. It follows that the small grain size of the magnesium alloys is a factor contributing to the formation of layer porosity.

Chill-Cast Test Bars

Some experiments were also carried out with chill-cast bars. With cylindrical cast bars a ring of porosity is found at a distance from the chill face. It was found difficult to control this annular porosity in chill



POSITION OF TEST BAR (SEE FIG. 1C)

	A	B	C	D	G
Voids, per cent	0.6	0.6	0.1	0.1	—
$\frac{UTS \times 100}{UTS_{DTD}}$	42	65	61	79	50

Fig. 10—Temperature distribution during solidification and mechancial properties of test bars in 93/7 Mg-Al top-fed casting poured at 1364° F. (740° C.) into green sand mold. Feeder to casting ratio, 1:1.

Table 2

CORRELATION BETWEEN PROPERTIES OF CASTINGS AND COOLING CONDITIONS IN THE MOLD

	Casting Conditions				Properties of Castings								
					Porosity Voids, per cent				Relative Strength $\frac{UTS \times 100}{UTS_{DTD}}$				
Alloy	Pouring Temperature, ° C.	Feeder/ Casting Ratio	Mold Condition	Solidification Factor	A	B	C	D	A	B	C	D	G
93/7	740	1/1	Green	0.89	0.6	0.6	1.1	0.1	42	65	61	79	50
	740	1/1	Preheated*	9.4	0.7	0.4	0.4	0.0	73	86	79	98	76
Mg/Al	780	1.6/1	Green	2.8	0.6	0.3	0.8	0.1	70	74	64	77	62
	780	1.6/1	Preheated*	54.0	0.7	0.4	<0.1	0.0	77	75	77	89	84
95/5	770	1/1	Green	1.7	<0.1	0.1	0.3	0.1	109	75	51	102	50
	780	1/1	Preheated*	8.8	0.3	0.0	<0.1	0.1	100	81	84	98	73
Mg/Ni	800	1.6/1	Preheated*	15.5	0.4	0.0	0.0	0.1	100	88	86	97	80
93/7	770	0.5/1	Green	2.5	1.0	0.7	0.7	0.2	79	67	65	100	51
	770	1/1	Green	4.0	1.1	0.3	0.2	0.0	71	75	79	105	74
Al/Cu	780	1/1	80 gm. chill†	0.89	1.2	0.7	0.9	0.2	52	72	64	90	50
	780	1/1	120 gm. chill†	0.92	1.0	0.4	1.4	0.5	63	74	40	67	34

*Mold face heated to 100° C.
†Light chills of this total weight embedded along whole length of bar.

castings and to obtain reproducible results with castings solidified under apparently identical conditions.

To control the solidification conditions more precisely the molten metal was held in cylindrical iron containers which were at the same temperature as the metal, and these were then lowered into baths of solder maintained at a constant temperature. It was hoped in this way to control the conditions of freezing exactly, and to be able to reproduce the annular type of porosity at will.

It was shown that fine-grained material tended to form annular porosity, but coarse-grained beryllium containing material showed central shrinkage. However, marked annular porosity was not always found in fine-grained material, and some other factor may operate which makes it difficult to invariably reproduce annular porosity in such material even with this close control of solidification conditions.

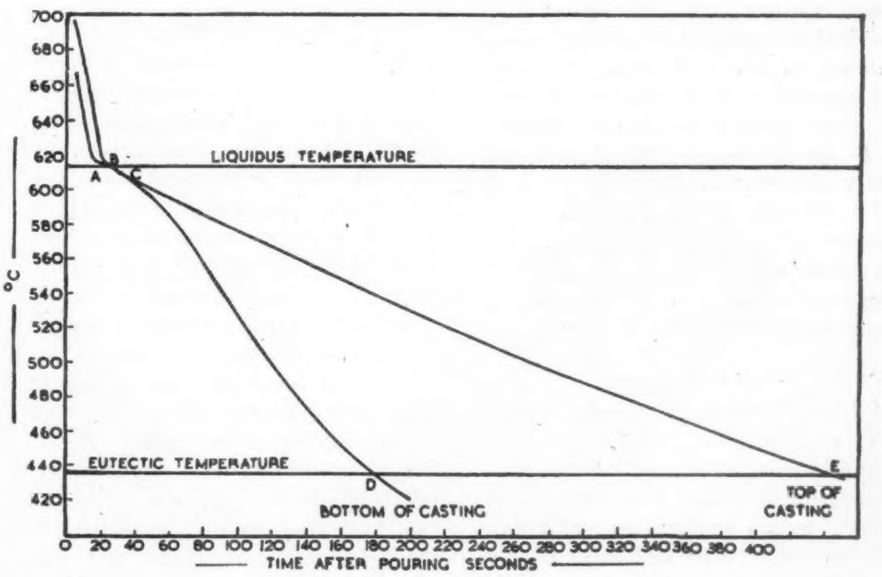
That annular and layer porosity are essentially similar and arise from the same cause was proved by a sand-cast bar poured unusually cold, which showed annular porosity in that part of the bar where the metal could freeze most rapidly, merging into the normal layer type further along the bar. In the intermediate region the porosity took the form of a series of small layers normal to the mold wall but arranged in an annulus.

Experiments with magnesium-zinc (7 per cent) alloys showed that these alloys were moderately fine-grained and contained layers of porosity similar to those described previously except that the layers were deeper. In certain castings there were layers of eutectic similar in form to the layers of porosity shown in Fig. 14.

VII. Mechanism of Microporosity in Magnesium Alloys

Much of the mystery that has hitherto surrounded the occurrence of microporosity in magnesium alloys disappears with the findings (a) that under comparable conditions of solidification the strength of unfed castings in both magnesium and aluminum alloys is affected to the same extent, and (b) that it is more difficult to ensure correct solidification conditions in magnesium than in aluminum alloys.

It is proved that microporous areas in both magnesium and aluminum alloys are deficient in the last liquid to solidify, and that the porosity is therefore essentially due to shrinkage. Some differences between the two materials still remain for



POSITION OF TEST BAR (SEE FIG. 1C)

	A	B	C	D	G
Voids, per cent	0.7	0.4	<0.1	0.0	—
$\frac{UTS \times 100}{UTS_{DTD}}$	77	75	77	89	84

Fig. 11—Temperature distribution during solidification and mechanical properties of test bars in 93/7 Mg-Al top-fed casting poured at 1436° F. (780° C.) into mold heated to approximately 212° F. (100° C.) Feeder to casting ratio, 1.6:1.

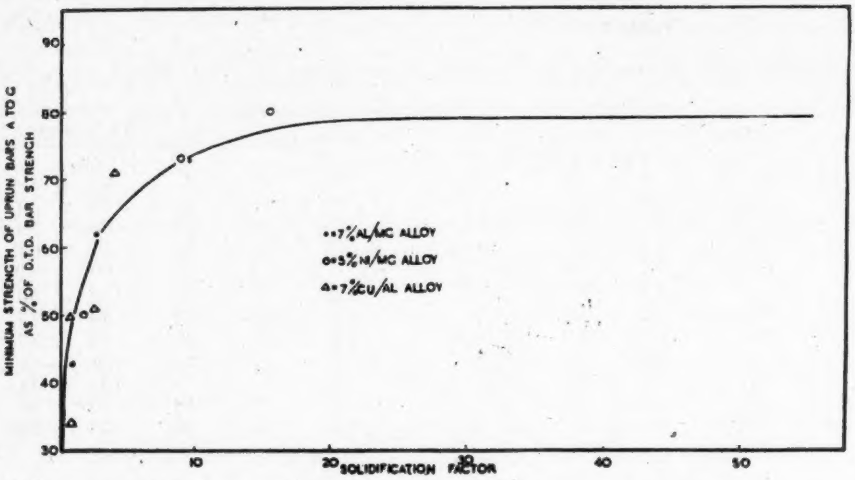


Fig. 12—Effect of solidification factor on minimum strength of up-run bars.

explanation, which must be somewhat speculative. These are as follows:

1. Under the same solidification conditions magnesium alloys show by density measurements less overall porosity than aluminum alloys.

2. For a given amount of porosity, judged by density measurements, the strength of magnesium alloys is more seriously affected than that of aluminum alloys.

3. Gas in aluminum alloys may alter the form and/or distribution of porosity in an unfed casting, so that in some cases the strength is actually improved. In magnesium alloys gas does not affect the form of porosity, and no tendency to give a more uniform distribution of porosity or to improve the strength has been observed in this work.

4. Porosity in fine-grained magnesium alloy takes the characteristic layer form in sand casting and frequently appears as an annulus in cylindrical chill castings.

Dendrite Forms

These observations may be largely explained by the form of the dendrites in cast magnesium alloys. The dendrites in magnesium alloys form small rosettes with six main branches on one plane and with little if any growth at right angles.

Typical dendrites in magnesium alloys are shown in Fig. 13. In metals which solidify in the cubic system the dendrites tend to grow equally in three directions at right angles parallel to the faces of the cube. It is reasonable to assume that there is less likelihood of interlocking of the hexagonal dendrites as compared with cubic dendrites, since the former tend to grow in one plane and there is less chance of residual liquid being trapped and forming shrinkage or gas voids between the branches of the hexagonal dendrites.

Any shrinkage of liquid so trapped between the branches of the hexagonal dendrites is fed from one side or the other of the flat hexagonal plate. Hence, the overall soundness of magnesium alloys is greater, judged by density determinations, than for cubic metals.

Grain Size Effect

An added factor which is likely to contribute to the overall soundness of most cast magnesium alloys is their fine grain as compared with that of most aluminum alloys. A fine-grained material is more likely to feed with movement of the pasty mass of small crystals and liquid than is a coarse-grained material, where the large dendrites would tend to hinder mass movement.

If, as is suggested, the unsoundness in magnesium alloys will tend to concentrate at the outside of the hexagonal dendrites, whereas in cubic metals a large proportion may be trapped between the dendrite branches, it would follow that any unsoundness caused either by shrinkage or gas would have a more serious effect on the strength of hexagonal metals.

The occurrence of layers of porosity in magnesium alloys has been shown to be associated with the fine grain of properly melted metal. Coarse-grained metal does not show layers. It seems probable that these layers form at a late stage in freezing, while a pasty mass of small crystals and liquid is moving to compensate for shrinkage.

Apparently, local "faults" develop in this mass at right angles to its direction of movement and are pulled farthest apart at the center of a sand-cast bar where the movement is greatest. This mechanism is suggested by the observation on magnesium-zinc alloys, where it was found (Fig. 14) that the layers of porosity were in some cases associated with layers of low melting point liquid.

It seems likely that the faults developed in the moving mass of crystals may in some cases be healed by the influx of low melting point residual liquid, and the resulting pool acts as a local feeder at a later stage in freezing, the liquid draining away from this pool to feed freezing shrinkage in the adjoining metal. In other cases the faults may form at a later stage in freezing and may never then be healed.

In the case of chill castings the sound outer zone probably represents material which has solidified rapidly from the mold walls inward, and in the central, slightly unsound portion, mass feeding of small crystals and liquid has taken place. In this case the faults develop between the two zones. It should be remembered that the degree of porosity may be influenced by small variations in gas content below the limits detectable by the test used.

VIII. Magnesium Alloy Casting Technique

The most striking conclusion from the work described is that there is no essential difference between aluminum- and magnesium-base alloys in respect to loss of strength in unfed castings when the castings solidify at the same rate and under the same conditions of temperature distribution.

When a particular casting in a gas-free magnesium-base alloy shows a relatively greater loss of strength in unfed portions than would a gas-free aluminum alloy, this is because the magnesium alloy solidified much more rapidly than would the aluminum alloy, and the temperature conditions during solidification have therefore been less favorable.

The mechanism of microsporosity in magnesium-base alloys is essen-

tially similar to that of any other non-ferrous metal, and is due to the draining away of the last portions of the metal to solidify from parts of the casting which cannot be properly fed. Owing to the more rapid rate of solidification of magnesium alloys under similar conditions, they are more sensitive to poor temperature distribution in the mold.

It follows that the casting technique must be adjusted to ensure the best solidification conditions and proper feeding. In practice most magnesium alloy castings are bottom or middle run, and the metal is seldom poured directly into the mold through the cavity which is subsequently to act as a feeder. This is because of the danger of trapping oxide and flux in the casting if the metal flows in a turbulent, broken stream into the mold.

Such inclusions can seriously weaken the casting and make it highly susceptible to corrosion. At the same time, the necessity for bottom or middle running increases the difficulty of obtaining good temperature conditions in the mold, since, with top feeders, the metal which eventually reaches them is cooled as it runs through the mold and is cooler than the metal coming in at the bottom of the casting.

The experiments described in the following paragraphs illustrate this point and show the advantage of putting feeders at the bottom instead of at the top of the casting, since gravity is shown to play a minor part in feeding, at least in the last stages of freezing.

1. *Experimental Work.* Most of the work on various methods of running magnesium alloy castings was done on 7 per cent aluminum-magnesium alloy, but some tests were made on the proprietary alloys AZ31 (3 per cent Al, 1.5 per cent Zn, 0.3 per cent Mn) and A8 (8.5 per cent Al, 0.5 per cent Zn, 0.3 per cent Mn). The castings used were:

(a) Top-poured bars, Fig. 1B.

(b) "Conventional" bars, i.e., bottom poured with feeders at the top, Fig. 1C.

(c) Bottom-run bottom-fed bars, Fig. 1D.

2. *Results.* The advantages of a top-poured bar have been shown throughout the work of this research by the consistently high strength of the top-poured D.T.D. bars. These bars can be poured on the slope to avoid inclusions. The hot metal runs through the feeder cavity, heating it, so that the best temperature gradient is set up while the bar is solidifying. As the length of the bar increases it becomes more difficult to avoid inclusions and for the feeder at the top of the bar to accomplish its purpose.

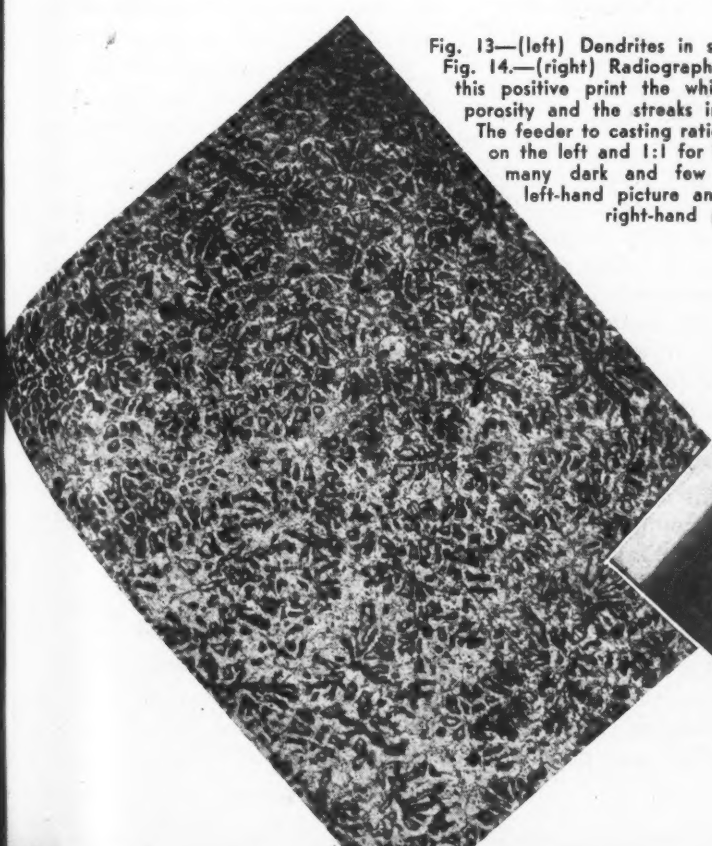
Strengths approaching those of D.T.D. bars were found using a very slow rate of pour with the bar tilted. The use of a slow pouring speed introduces one difficulty; the metal in the pot loses heat rapidly, and by the time the bar is filled the metal in the feeder head may be too cold to feed properly.

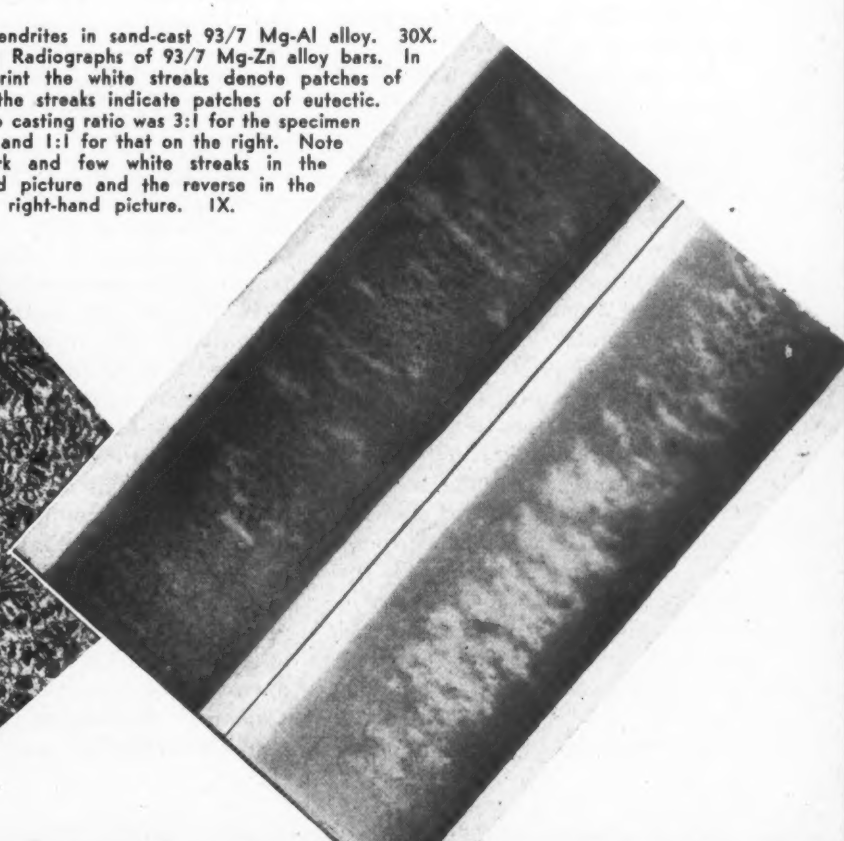
The most striking result was found on comparing the strength of the "conventional" and "bottom-fed" bars. Averaging all the results, and taking the strength of the D.T.D. bars as 100 per cent, the strength of the bottom-fed bars was 84 per cent, compared with 62 per cent for the "conventional" bottom-run top-fed bars.

The cross-section of the downgate must, of course, be large enough to maintain pressure of the liquid metal on the bottom feeder until a coherent skin forms around the casting proper, and if this is done gravity plays little part in the final stages of solidification and feeding. The advantage of the bottom-fed bar lies in the fact that the incoming metal passes through the feeder cavity and heats it, and comparatively cold metal reaches the top of the bar.

The temperature gradient during solidification is, in this case, from bottom (feeder cavity) to top. The

Fig. 13—(left) Dendrites in sand-cast 93/7 Mg-Al alloy. 30X.
Fig. 14.—(right) Radiographs of 93/7 Mg-Zn alloy bars. In this positive print the white streaks denote patches of porosity and the streaks indicate patches of eutectic. The feeder to casting ratio was 3:1 for the specimen on the left and 1:1 for that on the right. Note many dark and few white streaks in the left-hand picture and the reverse in the right-hand picture. 1X.





best results were found when the pouring speed was low enough to allow the metal to solidify just as the top of the bar was reached. With high pouring speeds the metal reaching the top of the bar was hotter and a less steep temperature gradient was set up. In heavy-section castings, in which the metal remains molten for a longer time, the possibility of convection currents causing the hotter metal to rise should also be kept in mind.

IX. Application to Foundry Technique

Although the results previously outlined are of considerable practical importance, they only show general principles. The castings made in magnesium alloys are much more complicated than the simple bars used in the laboratory, and it is seldom possible to run and feed a casting employing bottom runners and feeders only. In many cases it may be possible to get similar good conditions by middle running with the feeders at the ingates on the parting line.

There are also other ways of obtaining correct freezing conditions; for example, the side-running technique, in which the metal is admitted to the mold cavity by a side slit runner, or the use of a cross runner near the top of the mold, so that metal direct from the pot runs through it when the mold is nearly full and fills the top-feeder head with hot metal.

It is not possible to lay down hard and fast rules for good magnesium foundry practice since the casting technique depends so much on the particular casting, but the following points should be observed:

1. See that the metal is free from gas. This can best be done by using clean, dry metal that has not corroded in storage. If the metal has corroded, remove corrosion products by scratch brushing and preheat the metal out of contact with furnace gases, which usually contain much moisture. Test the melt by taking a small sample and allowing it to solidify under reduced pressure, as previously described. If the metal is gassy, allow it to solidify in the pot and remelt. The extra fuel involved is unimportant compared with the waste caused by porous castings.

2. Adjust the running and pouring conditions to ensure that the temperature conditions during solidification are such that the important parts of the casting solidify first and that the feeders are full of hot metal. The ideal to be aimed at is uniform progressive solidification in one direction from those parts of the castings remote from the risers to the risers.

Summary

Important factors to be remembered in casting magnesium alloys are:

(a) That magnesium alloys will lose heat more rapidly than any other commercial alloys when running through the mold.

(b) That feeder cavities can be preheated either by external heating (e.g., with a gas flame) or by allowing hot metal to pass through them.

(c) That feeder cavities need not necessarily be at the top of the casting since, provided the downgate is of sufficient cross-section, gravity is relatively unimportant in feeding, and hot metal will easily feed upward to parts of the casting where the metal is partly solid.

(d) That in the parts of the casting that matter most, the metal should remain as quiet as possible. Wherever a large volume of metal passes a particular point the sand becomes overheated. The metal at that point will remain molten longer and will feed nearby parts, and when it finally solidifies will contain shrinkage cracks or cavities. There is the added danger of gas pickup by reaction with the overheated sand.

(e) That dross and flux inclusions must be minimized by pouring as quietly as possible, and by the proper use of pouring basins and flux traps.

● COMMITTEE REPORT

STEEL DIVISION

Emphasizes Inspection Symposium

By Chairman T. N. Armstrong, International Nickel Co., New York

FOR a number of years it has been one of the Steel Division's objectives to arrange a symposium on a technical subject of particular current interest for the annual meeting. These symposia have been of twofold value, as they have not only brought the Steel Casting Industry up to date on a specific subject but they also have created interest for further investigation. This stimulation of technical research is, in itself, a contribution and should be one of the primary aims of a technical society if it is to provide the most useful service to its members.

It is necessary only to mention some of the proceedings of these sessions in past years to recognize how much they have contributed. Melting Practice, particularly acid electric, is a recurring selection as the art is still developing. Deoxidation practice has come in for a fair share of attention, and it was here that the discussion of the relation between aluminum deoxidation and intergranular sulphides was presented. More recently symposia were held on bore cracking in pressure castings and on centrifugal casting practice.

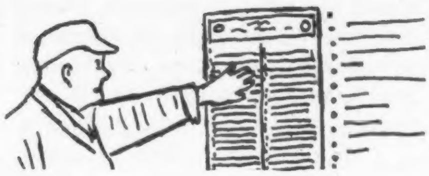
Selection of the subject for the symposium this year was influenced by some of the problems resulting from war production requirements. It was believed that discussion of inspection methods, including non-destructive testing and procedure for repairing defects in castings, would be not only of universal interest but would perhaps contribute more at this time than selection of another subject. It is regrettable that circumstances prevent holding the symposium, but it is hoped that publication of the papers in the AMERICAN FOUNDRYMAN will answer the purpose.

Delta Oil Receives "E"

THE War Department has presented the Delta Oil Products Co., Milwaukee, the Army-Navy "E" for the fifth time.

A Method of

Production Control



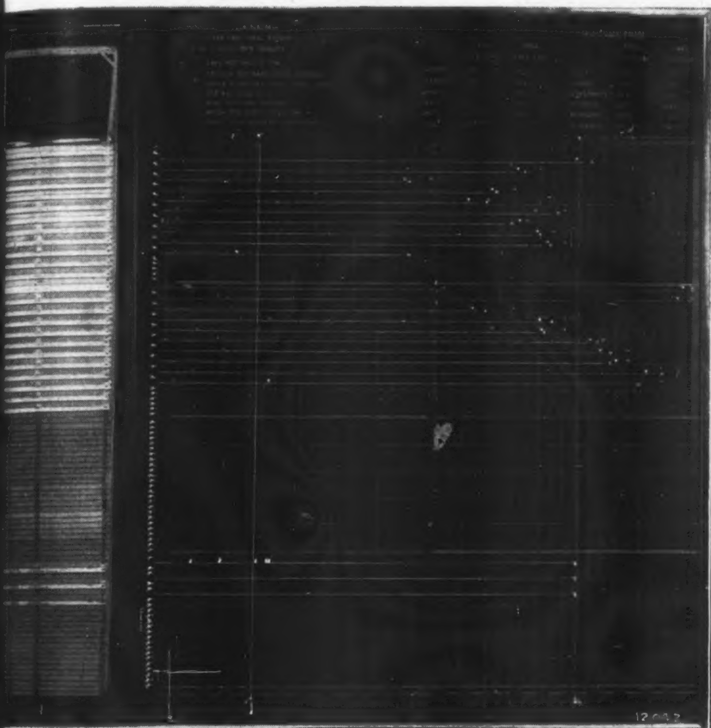


Fig. 1—A master control board, which shows overall production figures month by month.

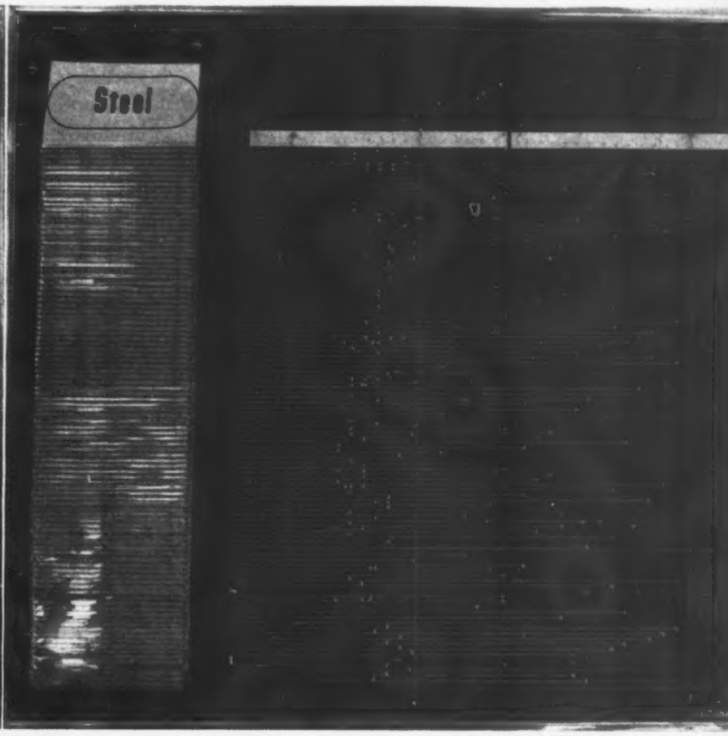


Fig. 2—Production control board which reports job status within the month.

• Production problems, aggravated by the unprecedented demands of the war years, have been met in many plants by control systems designed for particular plant conditions and accorded the cooperation of management and operating divisions. When service and costs again become vital factors in postwar production, control of the manufacturing process will be even more important than it is today.

THE present method of production control, in the foundry division of the company with which the author was associated, was installed early in 1944. The reason for this installation was to establish a systematic control of orders being processed through each department.

During this time, due to war contracts, more orders were being received than could be filled and, to further complicate matters, there were no means of determining exactly which orders could not be filled in accordance with the date specified by the customer's order.

It was necessary to make a thorough survey of every operation to determine exactly the changes to be made. This required a very careful analysis.

The completed report, with recommendations, was carefully reviewed by the management and approved with but few minor adjustments. The entire purpose of the installation was to obtain a maximum of production with a minimum of confusion and expense. A complete manual of duties and responsibilities was written and issued to every employee in a supervisory position. A production control department was created, and the entire system was built around standard production control boards. The detail of the system is done in the production control department where the control boards are located.

The control begins to operate with the plant load chart, which is de-

By George D. White, Production Control Supervisor,
Formerly with Enterprise Engine & Foundry Co.,
San Francisco

signed to reflect the total load in tonnage, by metal specifications, by month and by department, being carried at all times. From experience it is possible to obtain a maximum production figure.

When this figure is established it is a simple matter to load orders covering enough tonnage to enable a maximum month's production. On the other hand, management knows at all times the open capacity in each department.

Material and Priorities

Each order accepted by the company is sent to production control, where it is reviewed for priorities. If they are as required, the order is posted to one of the cards filed in the usual section of the control board, and thus gets a number for the control section use only. This placement on the control board is by month of required shipment, and the card carries the same information as is carried by the order.

A copy of the order with the delivery date travels to the production department whose work it is. It is here that the department schedule is completed. The work of departmental scheduling is the duty of the foreman of the interested department.

Proper control of material allocations and priorities are considered for each order. The scheduling is done to attain the maximum of production from each employee or piece of machinery.

One of the outstanding factors of successful operation is that the foreman has all the responsibility for the scheduling of his own work. He is fully responsible for the delivery of castings as specified by the order.

A copy of the schedule for the department is sent to production control and, as it tells when each order will be started and when it will be completed, the visual record on the production-control board may be started. This information will also be entered on the job card in the board file.

Each day a report is received from each foreman on the castings made the day before. This is received and the results posted by 9 am of the following day. The total quantity of each order cast and the weight is shown.

It also tells the status of each order upon which work has been started and, if a starting date has been reached and no work started, the reason for the failure is stated. This production status report is entered each day on the job cards affected, and as a job starts the red peg appears and progresses with the job.

Members Wanted for Production Control Group

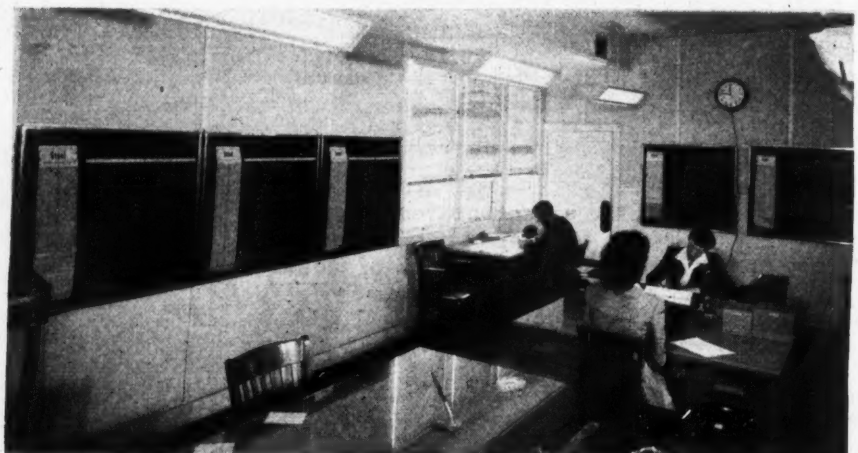
In connection with this paper on Foundry Production Control Methods, the first in a series now planned for AMERICAN FOUNDRYMAN, it is hoped that a general committee of foundry production control supervisors and managers can soon be formed. Such a committee would organize sessions at the annual A.F.A. conventions for presentation of papers and discussions.

Members interested in this work and who would like to serve on such a committee are invited to write to the Secretary of the Association, offering suggestions for a program. It is felt that there is a great possibility for the Association to aid production control managers in developing better methods through the exchange of information and experiences.

Among the many problems, one of the outstanding was that of decreasing the number of shop defectives. This could not be done in the office. However, the use of the boards and detailed reports taken from them gave each department a clear picture of its defective castings.

A "defective castings report" is prepared daily by each department and is sent to the production control office. This form shows the order number, pattern number, number of pieces rejected, total weight and the cause of the rejection. In showing the cause for rejection, it is a reminder to the foreman that immediate action must be taken.

At the close of each month a defective and rejected material report is prepared and issued to the depart-



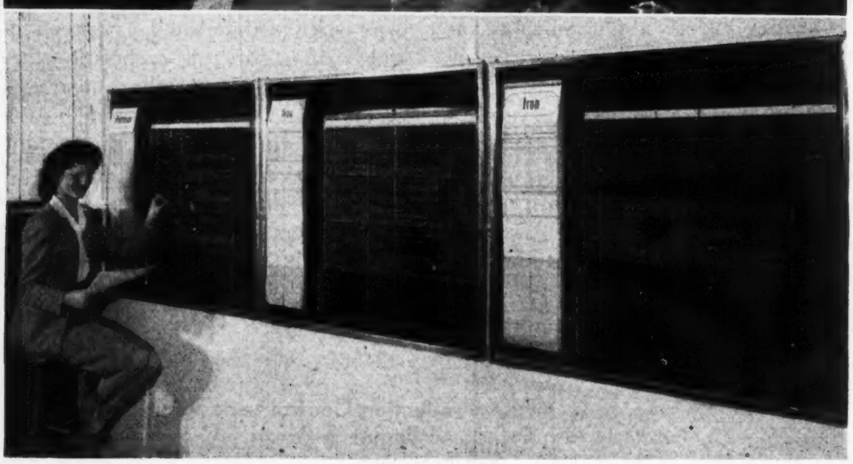


Fig. 3 (Top)—View of a production control department. Fig. 4 (Bottom)—Posting a daily report to a control board.

ment covered by the report. The report covers:

1. Part number.
2. Quantity cast.
3. Total weight.
4. Shop defectives.
   (a) Quantity.
   (b) Total weight.
5. Percentage of shop defectives.
6. Customer rejections.
   (a) Quantity.
   (b) Total weight.
7. Percentage of customer rejections.
8. Total percentage of loss.

The report was very valuable for the reason that it supplied the information needed by the department heads and management. In a period of 9 months the defectives were cut to an astonishingly low figure. Not only did the decrease in shop losses help the operations from a profit point of view, but it made possible an increase in output which was so badly needed by the armed forces.

The production control boards are designed to cover each operation. These operations are shown by various colored pegs. A yellow peg has to do with patterns for the castings, and the yellow peg placed in any one of the first three vertical sections denotes that the pattern is on hand, will be furnished by the customer or is to be made by the company.

When a job is scheduled and the pattern is to be furnished by the customer, the yellow peg is placed on the board in a position that is 3 days before the job is to be started. If that pattern has not been received when that day is reached, production control starts the machinery to get that pattern, for it must be on hand for examination and any necessary repair before the order-starting date.

Scope of Control

The white job-numbered peg has a white string attached, this string being on a spring-loaded reel. When a job is pegged on the board the white job peg is pulled out to the completion date, which is always at least 5 days before the required shipping date, allowing sufficient time for finishing operations before shipment.

The green peg denotes the starting date of each job.

The red peg appears between the green peg and the white peg and shows the progress of the work on the order, progressing each day by the percentage of completion of the order.

Shipments are made only after being authorized by production control, and when shipment is authorized a blue peg appears on the board. The reasons for the authorization are to obtain the most economical shipping rates, assure the customer of ample castings for machining purposes, and to control the orders from a cost accounting point of view.

When the daily report of castings poured shows that an order has fallen behind, a red flag appears on the board on the date of the lag.

Each day a vertical white string progresses across the board. This is a guide to the conditions for that day.

A status report showing the order number, part number, quantity on order, specified delivery date and reason for delay of production is prepared twice a week, and copies are sent to the plant manager and foreman of the department involved. Upon receipt of the report the foundry foreman immediately contacts the plant manager, giving the latter full information as to why the orders are behind schedule.

Located in the plant manager's office is a control board which has been set up as a master board, reflecting the overall production figures. Shown on this board are production figures for a two-year period for each department. In this way a chart is formed for that period.

All of the foregoing control method has been installed and is now used as a tool by management. It may be defined as a series of functions which coordinate the plant facilities and regulate the orderly movement of goods through their entire manufacturing cycle. Control starts with the receipt of a purchase order from the customer and follows through to the shipment of finished goods—at the proper time—to the proper place—in the required quantity and of the specified quality.

Magnesium Committee Adds D. W. Moll to List

THE A.F.A. Aluminum and Magnesium Division recently added D. W. Moll, vice-president, Hills-McCanna Co., Chicago, to its Executive Committee personnel.

Mr. Moll is chairman of the casting division, Magnesium Association and also a member of the board of directors.

(Photos courtesy H. F. Scobie, University of Minnesota)

Candid shots of the Chapter Chairman Conference held in Chicago July 17-18.

Fig. 1—Upper half of high pressure turbine casting. Markings indicate areas designated for magnetic particle and gamma ray inspection.

Removal and Repair of STEEL CASTING *Defects*

By R. A. Pomfret, Materials Engineer,
Bethlehem Steel Co., Shipbuilding Div., Quincy, Mass.

NON-DESTRUCTIVE tests, in conjunction with repair welding of castings, have been in use on an increasingly large scale at the Quincy shipyard for the past 10 years. The reasons for the apparent misplacement of the inspection facilities at the plant of the consumer rather than at that of the producer of the castings can be summarized as follows:

1. Originally, radiographic tests were not required for all castings in a given service, but only for those castings in which major defects were discovered during machining. Thus, the inspection facilities were first installed at the plant where the castings were machined.

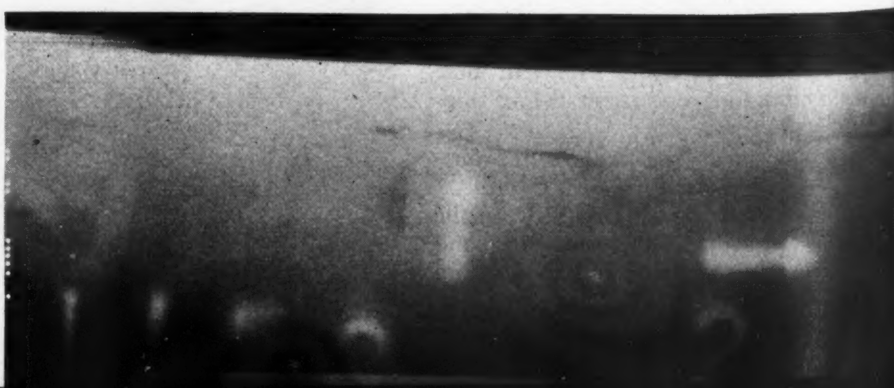
2. When general radiographic inspection of castings for a given service was required, the exposure times required for gamma ray technique were of such length that a considerable time saving could be gained by inspecting the thinner walls of a rough machined casting.

The present practice of requiring general radiographic or magnetic particle inspection for castings in which quality must be assured, as well as the use of high voltage x-ray and improved gamma ray technique, has largely nullified the reasons for placing the inspection facilities at the plant of the consumer; and we now find foundries cooperating in the effort to produce dependable castings by setting up non-destructive testing facilities and furnishing completely inspected and repaired castings which can be machined and installed in service without difficulty.

The increased use of these searching inspection methods naturally has resulted in a corresponding increase in the number of repair welds necessary, which is reflected in the increased cost of the finished casting. This cost can be reduced only by improving repair methods or by reducing the number of casting defects.

Repair costs have been already greatly reduced by the use of flame gouging, in lieu of chipping, for the removal of defects preparatory to welding, and the most promising field for further cost reduction appears to be in reducing the number of casting defects by the foundries. These inspection methods should be useful tools for this purpose, if their results are properly interpreted and applied in the improvement of foundry technique and in recommendations for design alterations.

• Flame-gouging and welding as means of removal and repair of structurally unsound areas in critical castings have reduced casting repair costs. The more searching inspection methods now in general use have shown that repair welding can be eliminated to a great extent by provision for sub-sectioning and weld location in the casting design. Flame gouging-welding techniques for casting repair, as well as precautions to be observed, are described in detail.



This paper was secured as part of the program for the 1945 "Year-Round Foundry Congress" and is sponsored by the Steel Division of A.F.A.

Casting Defects

For the purposes of this discussion, "defects" will be considered only as structurally unsound areas which are required to be repaired under the *Navy Department Radiographic Standards,* or by similar codes. Routine dressing of the surface for improvement of appearance will not be considered. The welding technique followed in the repair of castings is discussed only insofar as it differs from normal welding.

In order to illustrate the methods of removal and repair followed at this yard, there has been selected a replacement turbine casting of old design wherein the foundryman did not have advantage of the subsectioning methods now commonly used in designing castings of this type. The likelihood of finding defects for illustration was increased.

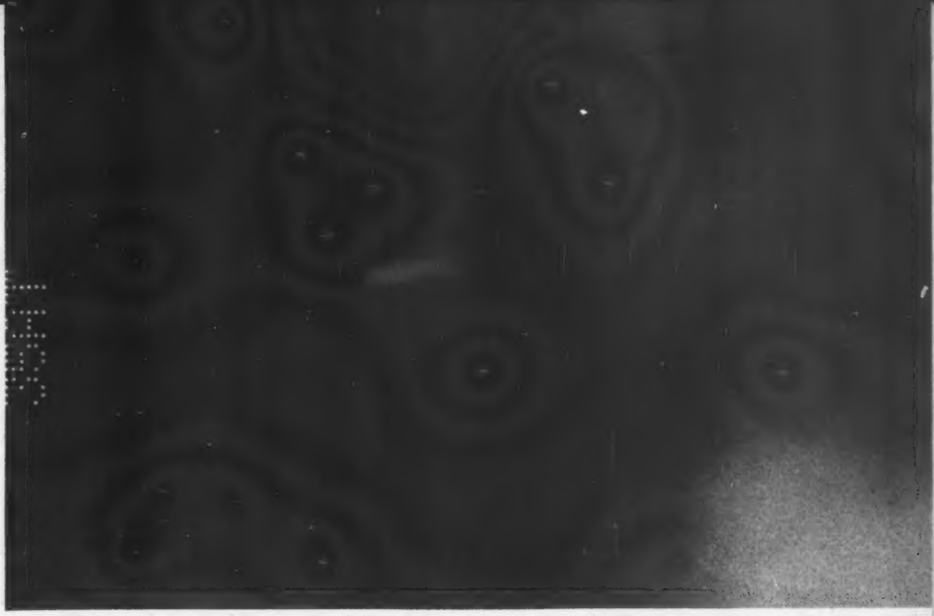


Fig. 2—Radiograph showing shrinkage area in side wall of by-pass valve.

Unfused Chills

The casting selected is shown in Fig. 1. Radiographic inspection indicated several instances of unfused chills in the flanges as well as rather pronounced shrinkage areas in the wall section of the by-pass valve. Figures 2 and 3 are typical radiographs of those sections.

The use of internal chills in castings of radiographic quality has been found to be undesirable and does not represent present-day practice, since, when they fail to fuse, the repair of the resultant defect may be more extensive than repair of the shrinkage which they were designed to avoid.

It will be noted in Fig. 4 that all flanged connections on this casting

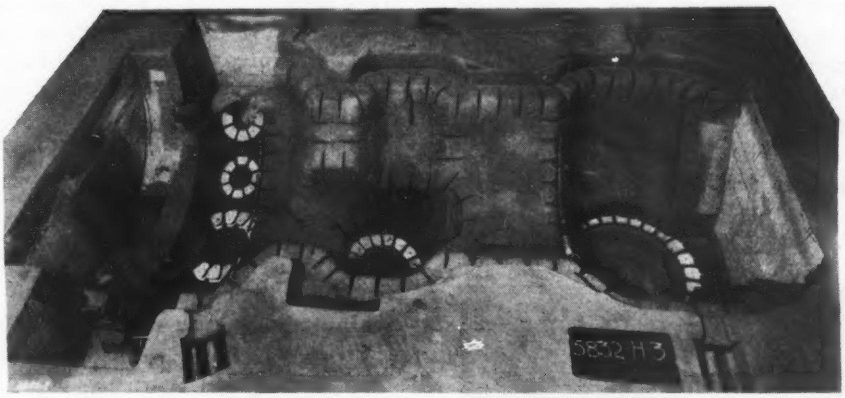


Fig. 4 (Above) — Mold for high pressure turbine casting. Note chill plates in flanged sections. This is obsolete practice, used only for purpose of illustration.

Fig. 3 (Left) — Radiograph showing unfused chills in heavy flange.

Fig. 5 (Right)—High pressure turbine casting. Shaded area indicates location of shrinkage area (see Fig. 2 radiograph).

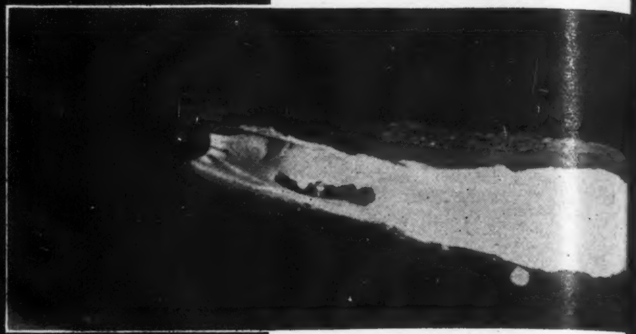


Fig. 6 (Left)—Use of standard cutting torch with flame-gouging tip in excavation of unfused chills.

Fig. 7—Close-up view of flame-gouging operation showing appearance of defect as molten metal is washed across it.

were rather heavily chilled. In the case of the by-pass flange, not only did the chills fail to fuse but the shrinkage which might otherwise have occurred in the flange extended the full length of the wall section, as indicated by the shaded area in Fig. 5.

The use of flame gouging in the removal of extensive defects of this type is particularly advantageous since the removal time usually may be measured in minutes, whereas the former method involving chipping would require hours. The equipment in use at this plant consists of a special cutting torch with flexible copper tubes and one of the bent, smaller sizes of flame-gouging tips, as shown in Fig. 6.

This operation, when properly controlled, results in the complete removal of the defect, with the removal of a minimum amount of sound metal. The defect can be seen by the operator during gouging and, therefore, it usually is possible to carry the operation to complete removal of the defect without frequent pauses for inspection.

Figure 7 illustrates the appearance of a shrinkage defect as a dark spot in the white molten metal surrounding it. Sand inclusions usually will appear as more highly incandescent areas than the surrounding molten metal.

Cracks may be more difficult to follow during the gouging operation, and sometimes may travel deeper into the casting if they are not completely removed before the flame-gouged cavity is allowed to cool. Shrinkage stresses in the cooling cavity will tend to concentrate at any remaining portion of the crack, causing it to open and extend to a greater depth.

An incompletely excavated crack usually can be seen if the cavity is examined immediately after gouging is stopped, when it will be visible in the cooling cavity. When these cracks are present, gouging should be resumed immediately in order to complete their removal before cooling has progressed sufficiently to set up stresses.

Flame-Gouging

The selection of flame-gouging operators is important, an essential requirement being that they be sufficiently familiar with the subsequent

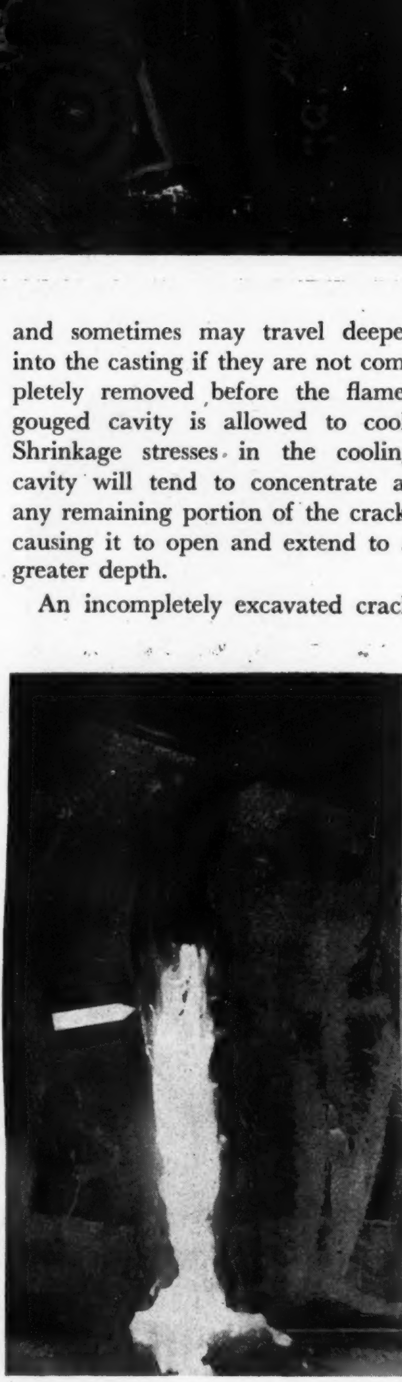


Fig. 8 (Left)—Flame-gouging shrinkage area in by-pass wall. Arrow indicates part of defect in molten stream.

Fig. 9 (Right)—Completed excavation of shrinkage defect in by-pass wall.

welding operations to shape the excavation to a form best suited for welding. In fact, the most efficient flame gougers at this plant are the welders themselves.

Flame gouging of the shrinkage defect (Fig. 2) is shown in Fig. 8. Since a completely sound repair can be assured only when the weld is laid on a sound base metal, it is necessary that the defect be removed completely. This usually is checked by magnetic particle inspection after excavation, particularly when the defect involved is a crack or tear. In this case, the excavation completely penetrated the wall of the casting, as shown in Fig. 9.

Welding Methods

After the flame-gouged cavity was cleaned of scale and sharp corners by peening and chipping, a back-up plate was tack welded to the inner wall of the casting, covering that portion of the cavity which penetrated the wall. The casting was then turned on its side, placing the cavity in position for flat welding which permits a high quality weld at the maximum rate of deposition.

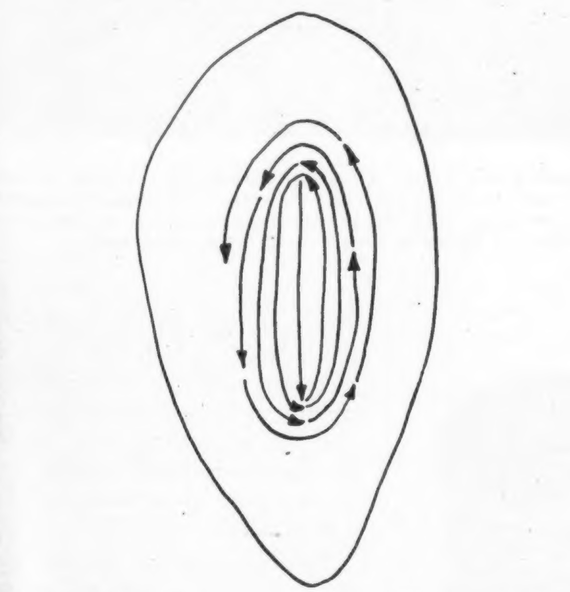
The weld was then made by starting at the bottom of the cavity, laying beads in a spiral fashion and working up the sides, as shown in Fig. 10. Each subsequent layer was deposited in a similar manner, as shown in Fig. 11, and in the sequence sketch, Fig. 12.

This type of procedure generally is used for welding larger holes in rigid sections in order to prevent welding stresses from building up and cracking the casting. By this method, the opposite sides of the cavity are not tied together until much of the weld shrinkage has already occurred.

The foregoing method is not necessarily followed near edges, or where the casting is less rigid, as in unsupported curved sections. A much faster method, which consists of a

Fig. 10 (Top)—View of casting in position for welding and sequence of applying initial beads, on side walls of cavity. Fig. 11 (Bottom)—Partially completed weld showing additional layers on sides of cavities.

Fig. 12 (Below)—Sequence of bead deposition followed for welding cavities in heavy rigid sections. Fig. 13 (Right)—Sequence of depositing woven or puddled layers in welding non-rigid sections where casting is free to contract.



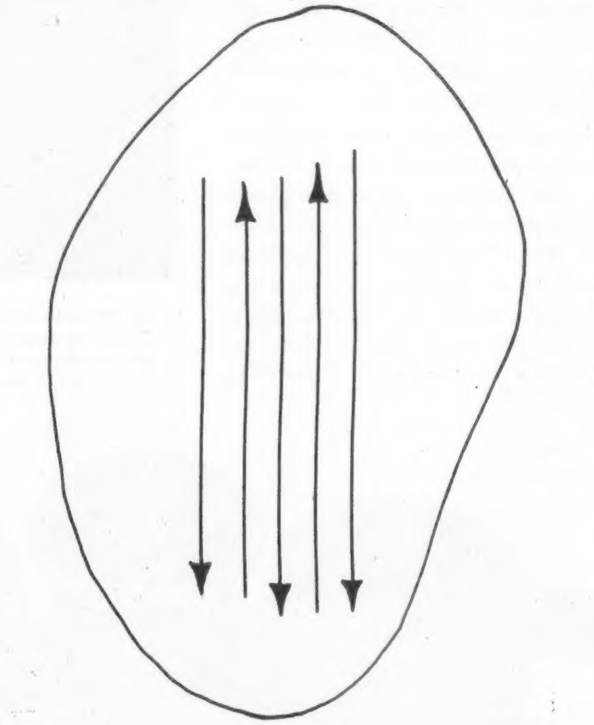


Fig. 14—Transverse defect of extended length welded in blocks in order to prevent distortion. Order of welding blocks was 2-1-3.

puddling or weaving technique, may be used.

In this method, the beads are woven to a width of approximately 1½ in. maximum and are built up in horizontal layers from the bottom of the cavity, as indicated in Fig. 13. It should be pointed out that care must be used in the application of this method because of the higher welding stress involved.

It sometimes may be desirable to use a combination of the two methods. For example, in a moderately rigid section, where the cavity is of such depth that less than ⅜ in. of sound metal remains, the beading technique would be used initially, carrying the beads only part way up the sides of the cavity. The puddling technique then could be used for the remainder of the weld.

Another combination of the two methods sometimes is used in the filling of a wide cavity when the weld is puddled only part way across the cavity, leaving one side free to contract, and then the final closing section is made by the beading method.

Block Welding

When the excavation of a defect produces a cavity of extended length, similar to a groove, it may be desirable to make the repair as a series of blocks rather than as a continuous weld. The transverse weld shown in Fig. 14 probably would have caused considerable bowing of the horizontal joint of the casting had it been made as a continuous weld.

Fig. 15—Repair of unfused chills in flange. Note that distortion is controlled by maintaining approximate balance of welding stresses. The three welds already completed are nearly evenly spaced at about 120°, and the two welds in process are 180° apart. Side retainer plates are placed to permit use of the puddling method.

However, the shrinkage stresses of block No. 2, which was made first, were not sufficient to overcome the rigidity of the remaining sound portions of the casting, and this block produced additional rigidity to resist distortion when blocks Nos. 1 and 3 were added.

This principle of selected placement of welds is followed throughout the repair of the casting as a whole. When defects are numerous and extensive, indiscriminate excavation and welding could result in an unacceptable amount of distortion.

Therefore, excavations are planned so that a minimum weakening of

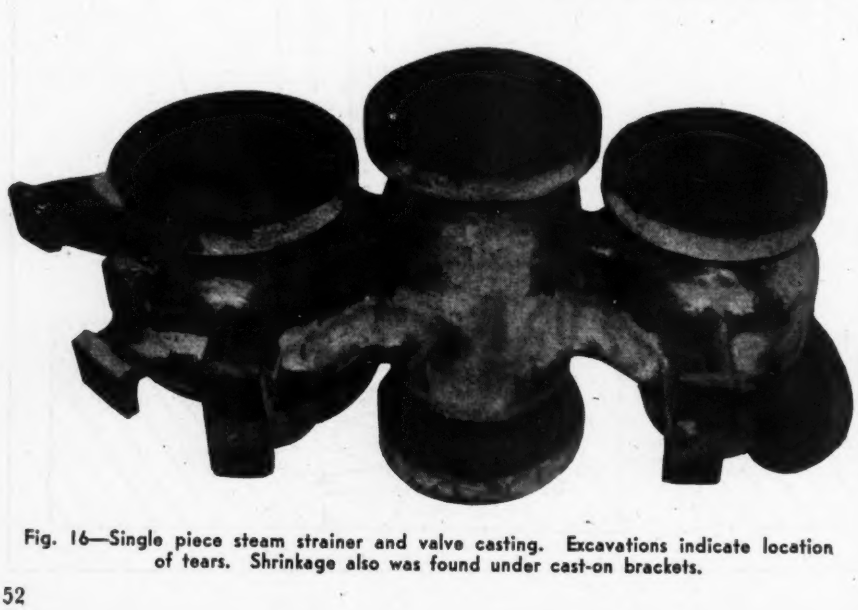


Fig. 16—Single piece steam strainer and valve casting. Excavations indicate location of tears. Shrinkage also was found under cast-on brackets.

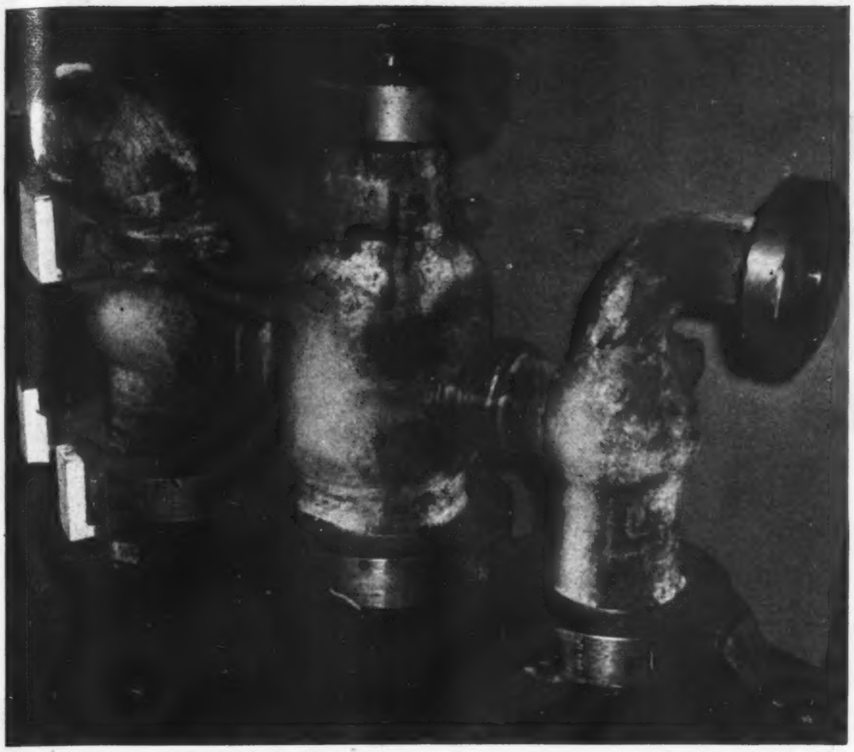


Fig. 17—Steam strainer and valve assembly made in three separate castings, with welded-on brackets and bosses.

the surrounding casting structure is caused, and defects in the metal adjacent to a cavity may not be excavated until the initial cavity has been welded. This principle is illustrated in the flange repair shown in Fig. 15. However, on rough flanges, these precautions normally would not be necessary.

Casting Design

The problem of weld location and sequence may be greatly simplified when the welds are incorporated into the design by sub-sectioning a complicated single-piece casting into two or more simpler castings. By the judicious use of welding in this way, repair welding can be eliminated to a great extent. However, effective application of this method requires closest cooperation between the foundry and the casting design agent.

In the single-piece casting shown in Fig. 16, difficulty was experienced with tears at the corners of the square pipe sections joining the center body with the two valve bodies on either side, as well as with shrinkage under the cast-on brackets. After discussion of these defects with foundry personnel, the design of subsequent castings of this type was changed to call for three separate body castings, with all brackets and bosses also cast separately.

The welding of these cast parts was comparatively simple and the need for unscheduled major repair welds was entirely eliminated. This welded assembly is shown in Fig. 17.

With regard to heat treatment, it is usual practice to employ a fairly generous preheat over the area affected by the weld when welding heavy sections. For carbon steel castings this will range from 100 to 300° F., the higher temperature being used for the thickest or most rigid sections. Excessive preheat for carbon steel should be avoided, since it has been found that an interpass temperature of above 600° F. may bring about a tendency toward porosity in the weld.

Carbon-molybdenum steel usually is preheated in the range of 300 to 600° F. Heat treatment after completion of repair welds usually consists of an all-over stress relief anneal at a temperature of 1150 to 1250° F., although some classification societies still require full annealing or normalizing and drawing.

Summary

Summarizing the points to be considered in planning the repair of castings, excavations should be planned to keep distortion from subsequent welding to a minimum. Individual defects should be excavated completely before welding is started, since unsound base metal may develop cracks in the repair weld.

In welding heavy, rigid sections, the use of preheat and the "beading" technique will aid in avoiding cracks or distortion due to excessive shrinkage. Major repairs in general should be stress relieved by heating the casting to 1150 to 1250° F. in a furnace.

Acknowledgment

The writer is directly indebted, for much of the work in connection with this paper, to E. F. Tibbetts, Engineer in charge of radiographic and magnetic particle inspection, and to A. G. Hogaboom, Welding Research Engineer.

Book Review

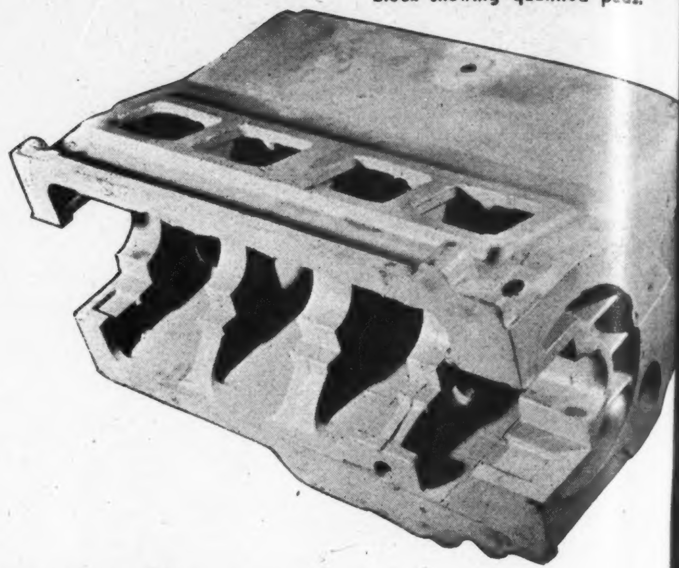
Dictionary of Engineering and Machine Shop Terms, by A. H. Sandy. Revised by I. E. Berck. Blue leatherette binding, 153 pages, 5½x8½ in. Published by Chemical Publishing Co., Inc., 234 King Street, Brooklyn, New York. Price $2.75.

This is an American revision of a British book. Consequently, its greatest value probably lies in its definitions of British machine shop and engineering terminology.

Even as a British publication, this book probably will be of little value to foundrymen. Some foundry terms are included in the book. However, the selection of these terms appears to be quite haphazard. For example, the author defines "drag," but does not define "cope." He defines "green sand," but he does not define "dry sand." Unfortunately, his definition of green sand omits the defining characteristic of green sand.

Since the selection of terms is British, it would be difficult for the writer of this report to positively state that the definition of the term "kish" is incorrect, since it may be that British foundrymen do have the impression that kish is a "slag which floats on the molten metal while being poured." However, in all of his contacts with British foundry publications, the term "kish," as used therein, refers to a form of graphite which separates from a carbon-rich molten iron on slow cooling.

Fig. 1 — Cast four-cylinder diesel engine block showing qualified pads.



CASTINGS *Should Always Be* QUALIFIED *in the Foundry*

By O. O. Gammon,

Chief Tool Designer, Caterpillar Tractor Co., Peoria, Ill.

• Methods of casting qualification in the foundry to reduce machine tool costs and facilitate machining are presented by the author, a particular point being the use of less highly skilled operators.

IN THE early 1920's, the demand for more production forced manufacturers to try to devise some ufacturers to try to devise some method of control of given points on castings. If parts could be produced uniformly enough in the foundry, the machining was fairly simple. However, with castings that had too much distortion, exterior roughness and uneven parting lines, targets had to be added to the first machining operation fixtures, with adjusting screws to juggle the casting around to equalize the distortion between the faces to be machined. This was a slow process, requiring care, and resulted in idle time for expensive machinery with a consequent loss of much production, but it could be accomplished by skilled operators.

Locating Bosses

The first attempt to better this condition, to the writer's knowledge, was the establishing of bosses on the casting which were hand filed by the manufacturers[1,2]. In filing, the casting was placed in a fixture fitted with a series of adjusting screws. The casting then was moved until it matched with targets on the fixture, which were of the same contour as the faces to be machined. The pads then were hand filed until level with blocks on the fixture set at a predetermined height. This was not entirely satisfactory, as in filing the pads usually were not square and there was not close enough dimensional control. The method was slow and, consequently, expensive.

The present-day methods are the grinding or machining of bosses, the number and location being the result of a study of the part involved for subsequent machining. Usually, three bosses are required on the casting face which is to be the bottom in the first machining set-up. These three bosses furnish a three-point leveling condition for horizontal and vertical planes. Two bosses at the extreme end of a side face insure squareness of location in the fixture, and one boss at the extreme end provides an end locating point.

An example of such preparation is the cast block for a four-cylinder diesel engine, shown in Fig. 1. In this case, the three bosses are on the side of the block, which is the bottom side for the first machining operation. The end boss, in this case, has no function in the first machining operation, but is used in locating the casting for a succeeding operation, in which the flywheel housing and timing-gear housing faces are to be milled.

Fig. 2—Qualifying grinding fixture.

In checking this casting at the foundry, it is placed in a fixture with adjusting screws, and juggled to match a series of fixed templets. The points checked include faces, contours, bores and close interference points.

Grinding and Milling

After the casting has been checked and clamped into position, location bosses are carefully ground with a portable hand grinder until sweep gages show that they are correct, as shown in Fig. 2.

When milling locating spots, much the same treatment is applied to the casting as in grinding. In qualifying fixtures where the spots are to be machined, the casting is supported on adjusting screws to position it with relation to the targets. Shaped targets or templets made from cold-finished sheet steel are employed, for checking the size, shape and location of various bosses and other surfaces. These targets can be mounted either in fixed positions or on sliding support arms, which can be withdrawn to permit clearance to

This paper was secured as part of the Program for the 1945 "Year-'Round Foundry Congress" and will appear in an "Inspectors Manual" to be published by your Association. Suggestions for the "Manual" will be appreciated by the Inspection of Castings Committee of A.F.A.

facilitate loading and unloading of the part. Care must be exercised in the design of these fixtures to provide as much visibility of the work as possible.

Many times, flush pins and scribes are used to determine the amount of stock to be removed for clean up. (Fig. 3.)

After the casting has been put in alignment, it is then clamped securely in place. The casting is now ready for milling, which is done with a special stop-collar holder, using a four-fluted end mill, cutting off center in order to eliminate tool pressure. A suitable air motor is supplied, with the correct rpm., and may be provided with an overhead harness for easy handling. The cutter holder is inserted in a hardened steel bushing on the fixture, a cutter inserted in the end of the spindle and held in place with a tie-bolt, then the cutter is rotated until the pad is milled, as shown in Fig. 4. The spot then can be checked by means of a flush-pin gage, made with the amount of allowable tolerance.

A ball-thrust bearing race contacts the shoulder of the counterbore in the head of the holder, which permits about a 3/16-in. stroke. Since the stock to be milled is about 1/16-in. thick, the locknuts are in contact with the head of the guide bushing throughout the milling operation. Locknuts are positioned on the sleeve of the driver when the driver is set up in a special gage developed for this purpose, as shown in Fig. 5.

Standardization

When contemplating having several different castings qualified in the same foundry, care should be given to standardization. All the equipment that would possibly be needed, other than the basic fixture and air motor, is shown in Fig. 5; namely, a cutter setting gage, driver, holder, flush-pin gage, and several cutters, which should be kept sharp by the vendor, who has the facilities.

Fig. 4—Application of milling on casting shown in Fig. 3.

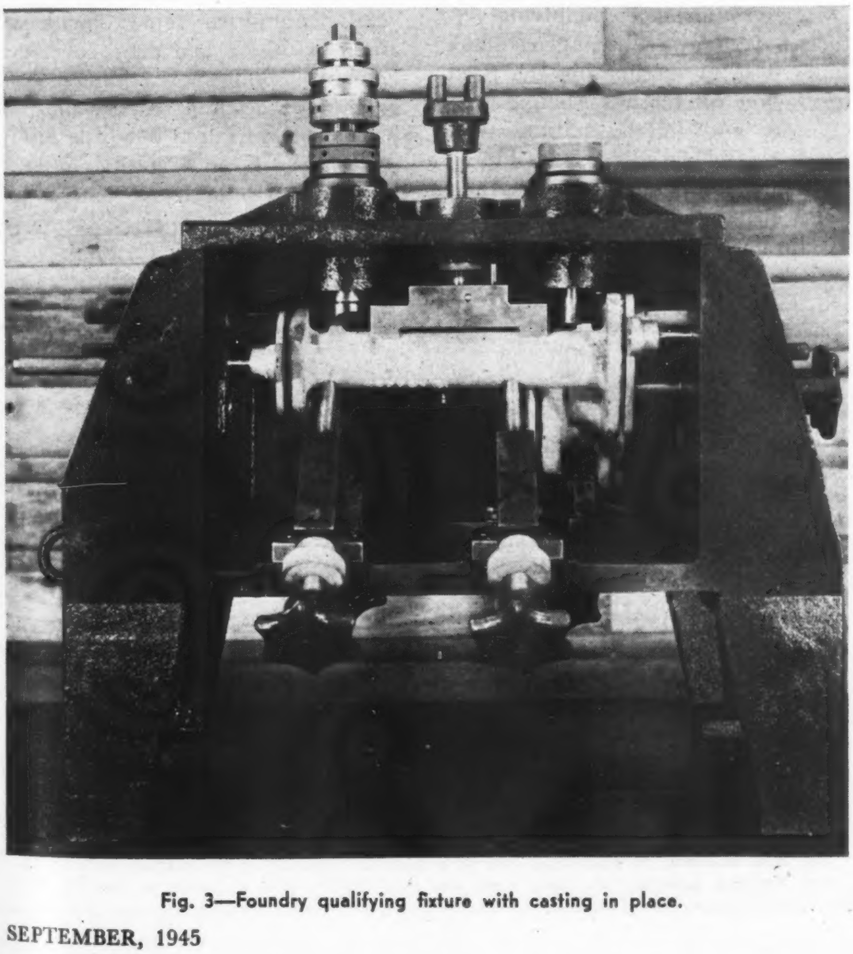


Fig. 3—Foundry qualifying fixture with casting in place.

Gray Iron Castings

It has always been thought that this method would not be acceptable on cast iron, having been used only on non-ferrous castings. This is entirely erroneous, as the casting shown in Fig. 6 is of cast iron. Note the front boss located at the top which was entirely removed to check the machining time and the amount of tool pressure required. This boss was originally ¼ in. in height and was removed in about 90 seconds with the equipment shown in Fig. 4, with no undue tool pressure. Normally, the amount of stock to be removed would be between 1/16 and ⅛ of an inch.

The gray iron casting, shown in Fig. 6, was not qualified, due to foundry scrap, but purely for manufacturing purposes. In this particular job, bores on opposite ends, done in two different machining operations, had to be held concentric to

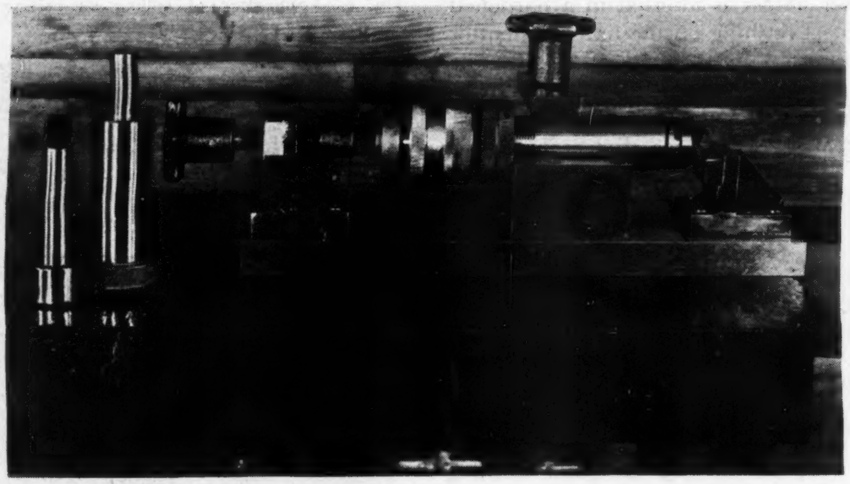


Fig. 5—Cutter-setting gage with holder in position; also, flush-pin gage and driver.

within 0.001 of an inch. It was impossible to chuck on a rough outside diameter and hold these limits. By locating on these finished spots, the seemingly impossible can be accomplished.

The use of prepared castings, with the routine inspection at the foundry, gives an opportunity for the foundry to find the source of faults, if any, and make corrections with a minimum of scrap and delay. Too, elimination of faulty castings at the source will prevent the waste of machining time on castings that will not clean up, and also will avoid payment of shipping charges on castings that will ultimately become scrap. In all cases, the manufacturer is willing to pay more for castings that have been qualified.

The tool costs of the first operation fixtures are greatly reduced, due to simplicity of fixtures that can be made to run qualified castings, thus eliminating targets and adjusting screws.

Production is greatly increased, thereby cutting the cost of machining. Operators with a lesser degree of skill can be used, and at this time skilled operators are not available.

In every instance, qualifying fixtures have paid for themselves many times over by eliminating the need for laying out castings before machining, and in the reduction of scrap resulting from machining errors on castings because they had not been located properly in the first machining fixtures.

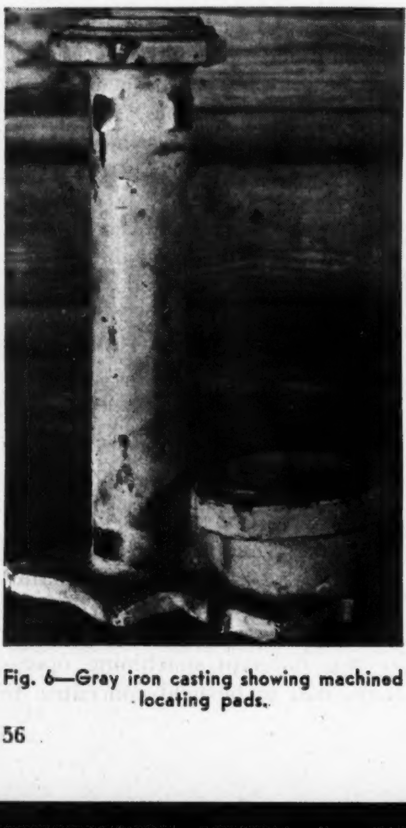


Fig. 6—Gray iron casting showing machined locating pads.

Reference

1. J. A. Macdonald, "Foundries Prepare Castings for First Machining Operation," *American Machinist*, Aug. 17, 1944, pp. 112-114.

2. B. H. Yingling, "Allison Eliminates Faulty Castings by Use of Target Inspection Fixtures," *American Machinist*, March 16, 1944, pp. 125-135.

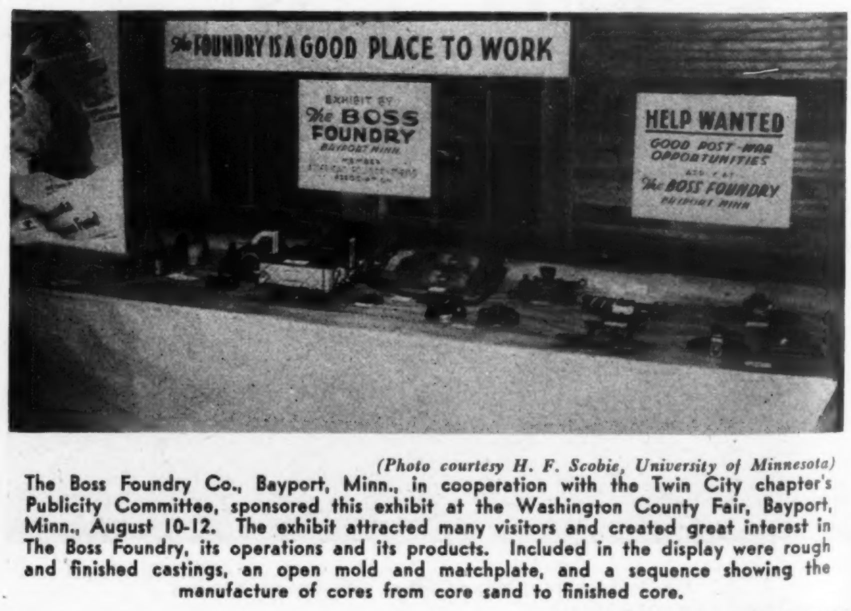
• COMMITTEE REPORT

Heat Treatment Committee To Publish Test Data

By Chairman E. R. Young,
Climax Molybdenum Co., Chicago

THE Committee on Heat Treatment of Steel Castings has continued in a stand-by status during the past year. The most important progress made in this field remains restricted because of the war.

A survey of the literature, and review of articles published on the subject of heat treatment of cast steel and pertinent articles on heat treatment in general, is in preparation for publication in the AMERICAN FOUNDRYMAN. The survey on the use of the end quench hardenability test, recorded as under way in last year's committee report, achieved about a 70-75 per cent coverage. Efforts to obtain more complete coverage for the final report on this project have secured but little information. It is now the committee's intention to publish the data in its present state. This report will appear in AMERICAN FOUNDRYMAN.



(Photo courtesy H. F. Scobie, University of Minnesota)

The Boss Foundry Co., Bayport, Minn., in cooperation with the Twin City chapter's Publicity Committee, sponsored this exhibit at the Washington County Fair, Bayport, Minn., August 10-12. The exhibit attracted many visitors and created great interest in The Boss Foundry, its operations and its products. Included in the display were rough and finished castings, an open mold and matchplate, and a sequence showing the manufacture of cores from core sand to finished core.

Gray Cast Iron

Tensile Strength, Brinell Hardness and Composition Relationships

By T. E. Barlow, Research Engineer, and
C. H. Lorig, Supervisor, Process Metallurgy Division,
Battelle Memorial Institute, Columbus, Ohio

• *Tensile strength, as one measure of gray cast iron quality, and Brinell hardness and chemical composition as alternate specifications for gray iron engineering applications do not necessarily result in irons produced under various conditions being of the same quality and possessing the same properties. The need for a simple method of correlating and interpreting these properties of gray cast iron to permit of more accurate applications is apparent.*

STANDARD methods for measuring the tensile strength of gray cast iron have been established for some years and are accepted by both foundrymen and designing engineers as one measure of the quality of gray iron castings. Furthermore, specifications on gray cast iron used for engineering application are usually either based on or include the values for the tensile strength ranging from 20,000 to 80,000 psi., depending upon the application.

Therefore, any discussion of tensile strength of gray cast iron, at the present time, would seem to be unnecessary and entirely repetitious. However, there are still some misunderstandings regarding the proper use of the tensile strength value for the purpose of interpreting the adaptability of gray iron castings and the interpretation of test bar results into engineering design.

The use of a tensile strength specification for gray cast iron has been criticized from time to time, on the basis that gray iron castings are not normally subjected to a tensile load, or at least to a load in any way commensurate with the sections involved. For this reason, both chemical composition and Brinell hardness have been used as alternate specifications by mutual agreement between the producer and the consumer.

Here again, however, misunderstandings may occur because of the fact that such specifications do not necessarily result in the production of equal quality irons from different foundries. Unfortunately, two irons of the same Brinell hardness, or even of the same chemical analysis, do not always exhibit the same mechanical properties, structure, or satisfactory combination of properties when produced under various conditions.

Mechanical Properties

It is believed that the reasons for observed variations in the quality of irons of either identical tensile strength, Brinell hardness number, or chemical composition require some discussion. There is an equal or greater need for some reasonably simple method of correlating and interpreting these properties of iron in order to facilitate more nearly correct applications of irons of different characteristics.

Basically — and practically — gray cast iron is not a material; it is a generic name for a "family" of materials possessing certain related characteristics.

In most cases, the tensile strength specification is not utilized as an indication of the ability of a given casting to resist a tensile stress. Its greatest value is as an indication of the other qualities of the gray cast iron which are required in any specific application.

For example, a casting consumer may rightly feel that a gray iron casting of 50,000 psi. tensile strength will be more satisfactory than one having a tensile strength of 20,000 or 25,000 psi. in an application in which the casting is submitted to various types of stresses, but in which no tensile stress is involved.

Unfortunately, the use of the tensile test as a measure of quality of gray cast irons does not take into consideration the fact that irons of a given tensile strength can and do vary widely in quality and behavior under other conditions, depending upon the chemical composition and the method of manufacture. For example, an iron produced by good melting technique and with a given "balanced" chemical analysis may exhibit a tensile strength of 45,000 psi. with a low Brinell hardness number and be relatively easy to machine.

On the other hand, another iron produced by a faulty melting technique, but of a composition which should permit of a tensile strength of 60,000 to 70,000 psi. may readily

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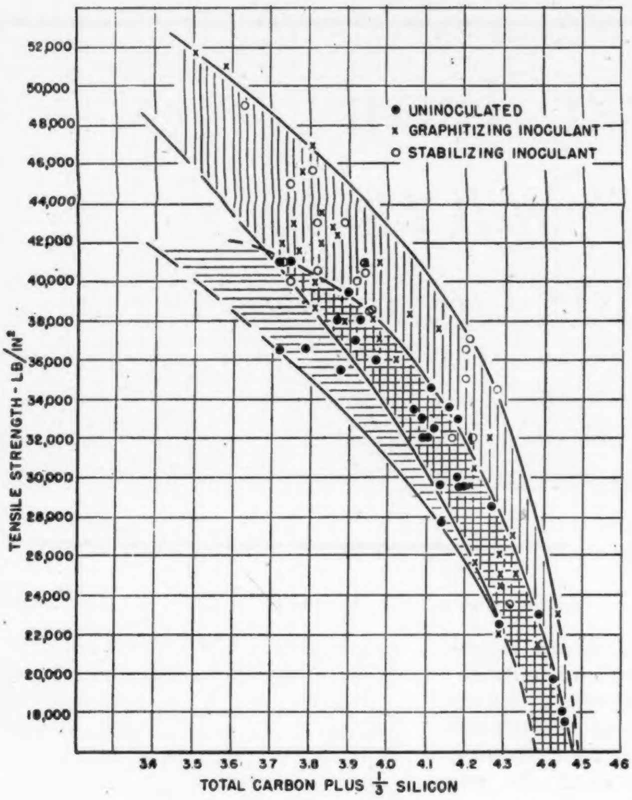
This paper was secured as part of the 1945 "Year-'Round Foundry Congress" and is sponsored by the Gray Iron Division of A.F.A.



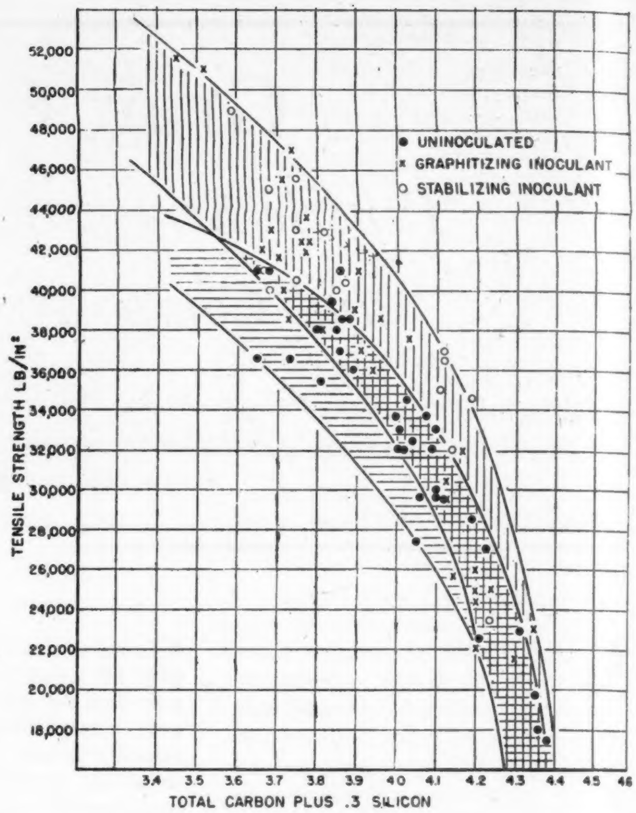
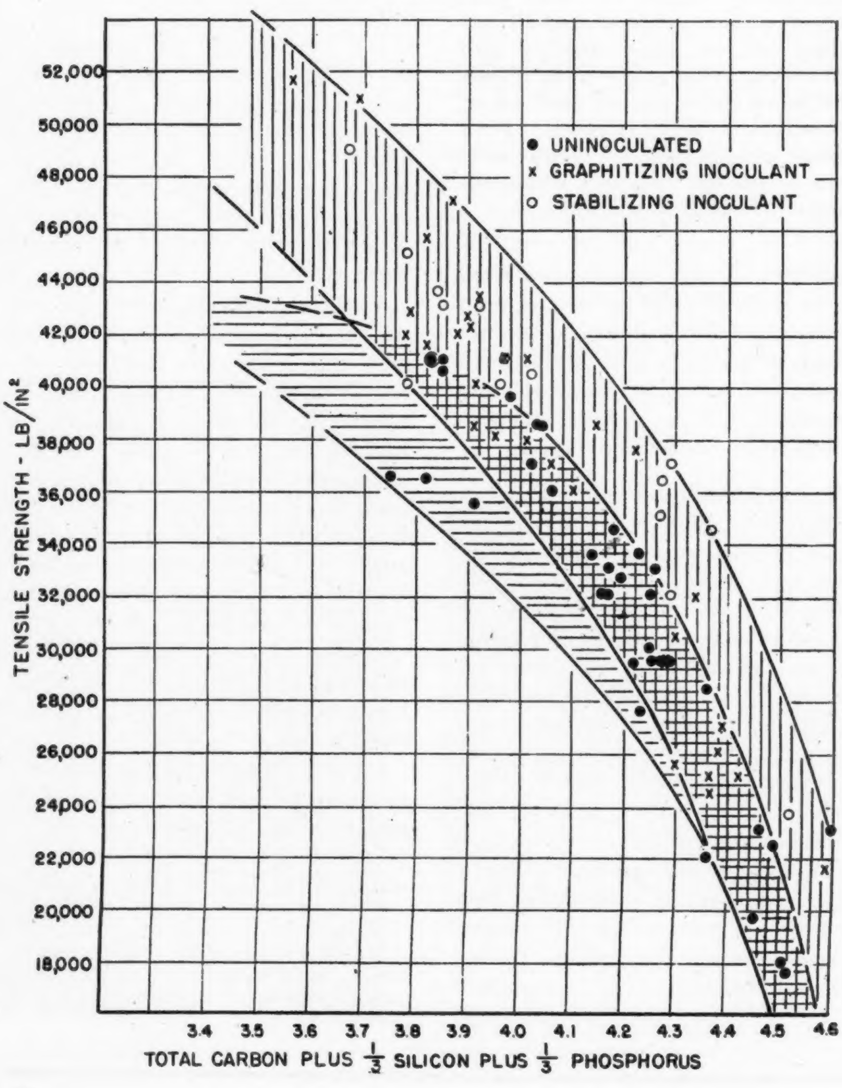


Fig. 1 (Top left)—Relationship between tensile strength and carbon equivalent (carbon plus 1/3 silicon) of gray cast iron.

Fig. 2 (Above)—Tensile strength and carbon equivalent (carbon plus 0.3 silicon) relationship. Fig. 3 (Bottom left)—Carbon equivalent (carbon plus 1/3 silicon plus 1/3 phosphorus) and tensile strength relation.



have the same tensile strength of 45,000 psi., but possess a high Brinell hardness number, and relatively poor machining characteristics, and be unsatisfactory in wear-resistance.

The use of the Brinell hardness number as a measure of quality is frequently unsatisfactory for the same reasons described previously. Such a test could only be entirely satisfactory as a measure of the quality of iron, if all the other factors of production were known and could be interpreted correctly. It is no news to most engineers that Brinell hardness number does not necessarily indicate the degree of machinability of gray cast irons made by different foundries and under dissimilar conditions.

The use of chemical composition alone, for the purpose of defining the essential characteristics of gray cast irons, fails for reasons similar to those applied to tensile strength and Brinell hardness.

Two or more identical gray iron castings of identical composition may

differ in physical and mechanical properties to the extent that an individual foundry may meet a chemical specification and, at the same time, inadvertently produce an unsatisfactory product from the standpoint of the engineer or consumer.

Relationship Between Tensile Strength and Chemical Composition. In an effort to clarify the relationship between the tensile strength and other properties of gray iron castings, the authors have made an attempt to show the extent of correlation between tensile strength, Brinell hardness, and composition with the aid of graphs plotted from information obtained on commercial gray cast irons produced by members of the Gray Iron Research Institute, Inc.

Perhaps the most important relationship is that between tensile strength and composition, since it offers a convenient measuring stick "for the foundryman, the engineer, or both."

Cast Iron Test Bars

For the purpose of this study, 82 commercially produced cast iron test bars were chosen at random from the hundreds of bars made available through a cooperative research effort being conducted at Battelle Memorial Institute. The test results and the chemical analysis of the irons used were obtained by the individual foundry in the course of routine control without previous knowledge of the fact that the results would subsequently be used for special study like the one undertaken.

Written discussions of this paper are solicited for publication in future issues of "American Foundryman" and/or bound volume of "Transactions." Discussions should be sent to Secretary, American Foundrymen's Association, 222 West Adams St., Chicago 6, Ill.

After the relationships which follow were established, their accuracy was demonstrated by utilizing information obtained from experimental gray cast iron melts, from other commercially produced gray cast iron melts, and from the data contained in the A.F.A. publications, CAST METALS HANDBOOK and ALLOY CAST IRONS, as well as in other handbooks.

The most logical approach toward establishing the relationship between tensile strength and chemical composition involved the use of what is known as the carbon equivalent concept. The method of presentation utilizes both the total carbon and the silicon contents of gray cast iron in the form of a single value.

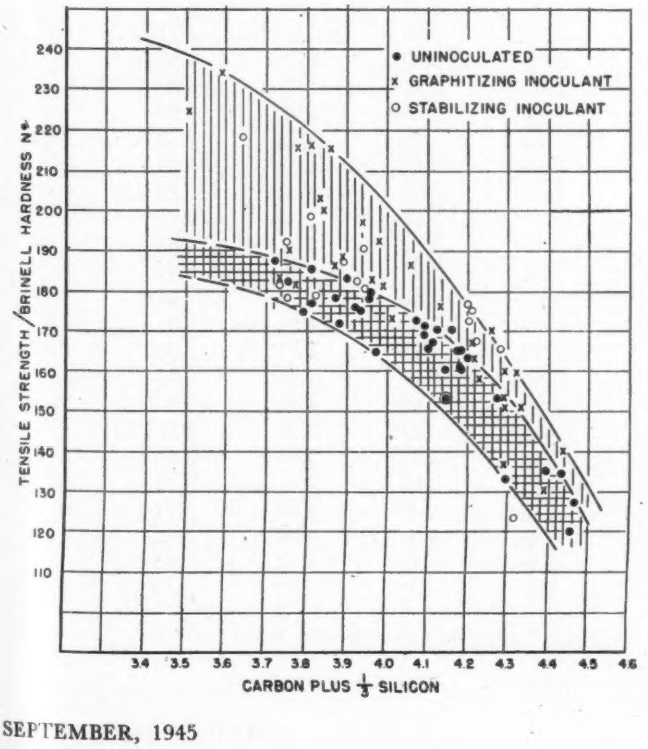
Although the percentages of total carbon, of silicon, or of carbon plus silicon have no significance in themselves in demonstrating a relationship between strength and composition, these values can, when utilized in accordance with the carbon equivalent concept, give a value, expressed in percentage, which may be plotted against the values for tensile strength or for other physical properties to show a simple relationship between composition and a property of the iron.

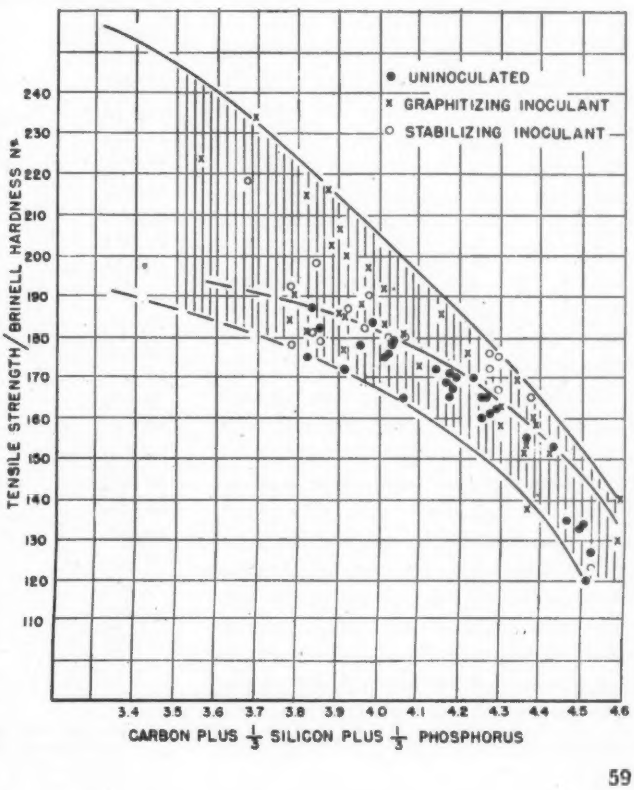
Alloying Elements

In the application of the carbon equivalent concept, normal manganese and sulphur contents must be assumed and the iron must be substantially free from alloying elements such as nickel, copper, chromium, molybdenum, and vanadium. However, similar relationships may be established for the alloyed irons when the amount and type of alloy is known and when its effect for any given carbon equivalent has been determined.

The published information on carbon equivalents indicated that there are several ways in which they may be calculated from the total carbon and silicon contents. In this work, five of these formulas have been

Fig. 4 (Below)—Relationship of tensile strength-Brinell hardness ratio to carbon equivalent (carbon plus 1/3 silicon). Fig. 5 (Right)—Tensile strength-Brinell hardness ratio and carbon equivalent (carbon plus 1/3 silicon plus 1/3 phosphorus) relationship.





utilized in order that the degree by which they differ, one from the other, could be determined. It was anticipated that one formula might prove more consistent than any of the other four in providing a relationship between composition and strength.

The gray cast irons used are listed in Table 1 and cover the range of total carbon content from 2.70 per cent to 3.70 per cent with silicon from 1.3 per cent to 3.0 per cent, and phosphorus from 0.06 per cent to 0.80 per cent. The carbon equivalents calculated from these data range from 3.45 per cent to as high as 4.64 per cent. This is considered normal for unalloyed gray cast irons within the tensile strength limits of 20,000 to 50,000 psi.

Although the calculation of the carbon equivalent of a given iron by the five methods permitted variations as great as 0.30 per cent in the ultimate value, it was observed that three of the five methods covered the range of such variations adequately, and that the other two were, to all intents, duplications of one or another of the three.

Carbon Equivalent Calculation

Therefore, in presenting the relationship between the tensile strength of gray cast iron and its carbon equivalent in the form of graphs, only three methods for the calculation of the carbon equivalent were utilized. The resulting graphs are shown as Figs. 1, 2 and 3.

Fig. 1 includes the data on tensile strength plotted against carbon equivalent derived from the formula carbon plus 1/3 silicon (C + 1/3 Si). Fig. 2 was prepared using the formula carbon plus 0.3 per cent silicon (C + 0.3 Si) for carbon equivalent, while Fig. 3 was prepared with the carbon equivalent derived from the formula total carbon plus 1/3 silicon plus 1/3 phosphorus (C + 1/3 Si + 1/3 P). The fields included by the shaded areas in Figs. 1, 2 and 3 are sufficient to include the regions covered by the five formulas for carbon equivalent.

Regardless of the method used for calculating the carbon equivalent, a definite relationship between the tensile strength and the carbon equivalent is obvious from the character of the shaded areas in Figs. 1, 2 and 3. As one would anticipate from the nature of the information, the data fall within zones or bands rather than on lines, even when the data are further divided by differentiating between those irons poured directly into test bar molds and those receiving, just prior to pouring, some type of ladle treatment referred to as inoculation.

It was not considered necessary to differentiate between those irons treated or inoculated with the so-called graphitizing type materials from those treated with the "stabilizing" inoculating treatment, since the difference is readily observed in the graphs.

In order to avoid the possibility that references to inoculated irons may not be understood, the following passage is quoted from the A.F.A. ALLOY CAST IRONS to describe the agents used in the inoculation treatment:

"Inoculants or inoculating alloys are those materials which are added to molten cast irons in the ladle for the purpose of altering or modifying the structure and thereby improving the physical and mechanical properties to a degree not explainable on the basis of the change in composition resulting from their use."

The stabilizing inoculants referred to in Figs. 1, 2 and 3 introduce small

Table 1

CARBON EQUIVALENTS OF 82 GRAY CAST IRONS

Tensile Strength, psi.	*Ratio of Tensile Strength to Brinell Hardness*	*Total Carbon + ⅓ Si*	*Total Carbon + .3 Si*	*Total Carbon + ⅓ (Si+P)*	*Total Carbon + .3 (Si+P)*	*4.3+C —(4.3-.33 Si) . (1-.1 P)*
51,500[1]	224	3.51	3.45	3.56	3.49	3.56
51,000[1]	234	3.59	3.52	3.69	3.61	3.65
49,000[2]	218	3.64	3.58	3.67	3.61	3.68
47,000[1]	216	3.81	3.74	3.87	3.80	3.85
45,500[2]	198	3.81	3.75	3.84	3.78	3.83
45,500[1]	215	3.78	3.71	3.82	3.75	3.82
45,000[2]	192	3.75	3.68	3.78	3.71	3.79
43,500[1]	200	3.84	3.77	3.92	3.85	3.89
43,000[2]	179	3.82	3.75	3.85	3.78	3.86
43,000[2]	187	3.89	3.82	3.92	3.85	3.91
43,000[1]	190	3.76	3.69	3.79	3.72	3.80
42,500[1]	216	3.86	3.78	3.90	3.82	3.92
42,500[1]	186	3.87	3.78	3.90	3.81	3.89
42,000[1]	184	3.73	3.66	3.78	3.70	3.75
42,000[1]	203	3.83	3.77	3.88	3.81	3.88
41,500[1]	182	3.77	3.70	3.82	3.74	3.82
41,000	182	3.75	3.68	3.85	3.77	3.85
41,000	187	3.72	3.65	3.83	3.74	3.82
41,000[2]	181	3.73	3.66	3.83	3.75	3.84
41,000[1]	192	3.98	3.90	4.01	3.93	4.01
41,000[1]	197	3.94	3.86	3.97	3.89	3.96
41,000[2]	190	3.94	3.86	3.97	3.89	3.96
40,500[2]	189	3.82	3.75	3.85	3.78	3.86
40,500[2]	180	3.94	3.87	4.02	3.94	4.01
40,000[2]	182	3.92	3.85	3.96	3.89	3.97
40,000[2]	178	3.75	3.68	3.78	3.71	3.78
40,000[1]	185	3.81	3.72	3.91	3.82	3.90
39,500	183	3.90	3.84	3.98	3.91	4.00
38,500[1]	186	4.06	3.96	4.15	4.04	4.16
38,500	178	3.95	3.88	4.03	3.95	4.03
38,500	179	3.95	3.88	4.03	3.95	4.03
38,500[1]	177	3.81	3.73	3.91	3.82	3.91
38,000[2]	183	3.96	3.90	4.01	3.94	4.01
38,000[1]	188	3.89	3.81	3.95	3.86	3.95
38,000	178	3.87	3.80	3.95	3.88	3.96
38,000	175	3.93	3.85	4.01	3.92	4.01
37,500[1]	176	4.13	4.03	4.22	4.11	4.22
37,000[1]	181	3.98	3.91	4.06	3.98	4.07
37,000	176	3.92	3.86	4.02	3.95	4.02
37,000[2]	175	4.21	4.12	4.29	4.14	4.28

(Table 1 continued on following page)

[1]Treated with graphitizing inoculant.
[2]Treated with stabilizing inoculant.

percentages of the alloying element chromium. Otherwise, there is no change in composition, other than that already indicated by the carbon equivalent. The lowest line in each of Figs. 1, 2 and 3 defines the range of minimum values obtained for the uninoculated commercial irons of the series studies, whereas the second line from the bottom defines the range of minimum values for all of the inoculated irons of the same series.

The top line in each of Figs. 1, 2 and 3 defines the range of maximum tensile strength obtained from the inoculated irons, while the second line from the top defines the range of maximum tensile strength obtained for the uninoculated cast irons of this series. In order to test the accuracy of location of the shaded bands of Figs. 1, 2 and 3, the values for tensile strength and carbon equivalent, contained in numerous publications together with other test bar results, were found to fall within the areas included in Figs. 1, 2 and 3.

Inasmuch as the data utilized in this paper cover a wide range of commercial melting techniques and foundry practices, it is reasonably safe to assume that the relationships indicated apply to most unalloyed gray cast irons being produced at the present time within the composition range indicated. It is possible that lower minimum values are obtainable under some conditions, but such occasions should be rare.

Although a value for phosphorus may be included as one of the variables of the carbon equivalent formula, on the basis of the theoretical effect of phosphorus on the eutectic composition of cast iron, the evidence in Figs. 1, 2 and 3 would indicate that using phosphorus in the formula does not improve the compatibility of the carbon equivalent-tensile strength relation.

The shaded zones shown in Figs. 1 and 2 (without the phosphorus) are narrower than the comparable zones of Fig. 3 (with the phosphorus). The only "high" phosphorus irons in the series studied are among those above 4.1 per cent in carbon equivalent.

As previously mentioned, the information presented graphically in Figs. 1, 2 and 3 was obtained from production heats of gray cast iron made under the widest possible range of cupola operation and foundry technique. Furthermore, all testing and chemical analysis was done using routine methods and in plant control laboratories.

A foundry, therefore, utilizing consistent melting, testing, and analyzing procedures may be expected to produce irons which will fall in a narrower band than those shown in Figs. 1, 2 and 3. For example, less scatter would probably have been obtained if standard ASTM methods or extremely accurate research methods of chemical analysis were employed instead of the routine check methods actually used.

Table 1 (Continued)

CARBON EQUIVALENTS OF 82 GRAY CAST IRONS

Tensile Strength, psi.	*Ratio of Tensile Strength to Brinell Hardness*	*Total Carbon + 1/3 Si*	*Total Carbon + .3 Si*	*Total Carbon + 1/3 (Si+P)*	*Total Carbon + .3 (Si+P)*	*4.3+C −(4.3-.33 Si)·(1-.1 P)*
36,500	175	3.79	3.73	3.82	3.72	3.83
36,500	162	3.72	3.65	3.75	3.68	3.75
36,500[2]	176	4.20	4.12	4.27	4.18	4.26
36,000	165	3.97	3.89	4.06	3.97	4.03
36,000[1]	173	4.02	3.94	4.10	4.01	4.10
35,500	172	3.88	3.81	3.91	3.83	3.91
35,000[2]	172	4.20	4.11	4.27	4.17	4.26
34,500[2]	165	4.28	4.19	4.37	4.27	4.36
34,500	167	4.11	4.03	4.18	4.09	4.18
33,500	170	4.16	4.08	4.23	4.14	4.22
33,500	172	4.07	4.00	4.14	4.06	4.13
33,000	165	4.18	4.10	4.26	4.17	4.25
33,000	171	4.09	4.01	4.17	4.08	4.15
32,500	170	4.12	4.04	4.19	4.10	4.19
32,000	165	4.17	4.09	4.25	4.15	4.24
32,000[1]	170	4.26	4.17	4.34	4.23	4.33
32,000	169	4.09	4.02	4.16	4.08	4.16
32,000[2]	167	4.22	4.14	4.29	4.20	4.32
32,000	165	4.10	4.02	4.17	4.08	4.16
30,500[1]	163	4.22	4.13	4.30	4.15	4.31
30,000	160	4.18	4.10	4.25	4.16	4.24
29,500	163	4.20	4.12	4.29	4.20	4.28
29,500	161	4.18	4.10	4.27	4.18	4.26
29,500[1]	167	4.21	4.13	4.28	4.19	4.26
29,500	160	4.14	4.06	4.22	4.12	4.21
28,500	155	4.27	4.19	4.36	4.27	4.35
27,500	153	4.14	4.05	4.23	4.13	4.22
27,000[1]	159	4.32	4.23	4.39	4.29	4.37
26,000[1]	160	4.29	4.20	4.38	4.28	4.37
25,500[1]	158	4.23	4.15	4.30	4.21	4.30
25,000[1]	151	4.33	4.24	4.42	4.32	4.40
25,000[1]	153	4.29	4.20	4.36	4.26	4.36
24,500[1]	151	4.29	4.20	4.36	4.26	4.36
23,500[2]	143	4.32	4.24	4.52	4.42	4.52
23,000	135	4.39	4.31	4.46	4.37	4.45
23,000[1]	140	4.44	4.35	4.64	4.53	4.60
22,500	133	4.29	4.21	4.49	4.39	4.48
22,000[1]	137	4.29	4.20	4.36	4.26	4.36
21,500[1]	130	4.39	4.30	4.59	4.48	4.58
19,500	134	4.43	4.35	4.50	4.40	4.48
18,000	120	4.45	4.36	4.51	4.41	4.49
17,500	127	4.46	4.38	4.52	4.43	4.51

[1]Treated with graphitizing inoculant.
[2]Treated with stabilizing inoculant.

Permissible Analytical Error

According to the ASTM standards for chemical analysis, the permissible error in analysis would account for a spread of 0.10 per cent in carbon equivalent. Inasmuch as highly accurate technique is not required in routine check methods, not all the analytical data utilized in obtaining Figs. 1, 2 and 3 can be assumed to be within the accuracy of 0.10 per cent carbon equivalent.

Hence, while one cannot question but that some of the spread in tensile strength shown in the graphs may be accounted for by variations

Table 2

RELATION OF STRUCTURE TO TENSILE STRENGTH-BRINELL HARDNESS RATIO*

Tensile Strength Divided by Brinell Hardness	*Structure*
210 and up	Normal graphite, smallest cell
190 to 210	Normal graphite, small cell
180 to 190	Normal or low percentage "Type D" graphite, medium cell size
160 to 180	"Type D" graphite, variable cell size
Below 160	Completely "Type D" graphite, large cells, or free ferrite

*Written discussion by T. E. Barlow and R. G. McElwee, A.F.A. TRANSACTIONS, vol. 50, p. 1099 (1942).

in structure of the metal which may also profoundly affect the tensile properties, still part of the spread could arise from inaccuracies in the analytical and physical data.

Since the relationship between tensile strength and carbon equivalent takes the form of a band or zone, rather than a single line, relative position within the zone may be a direct measure of relative quality. For example, irons defined by the upper limit of the shaded area in Fig. 1 may be considered to be "premium" irons.

The structure of such "premium" irons would indicate maximum resistance to wear, maximum transverse properties (including deflection), maximum machinability for the strength obtained, and maximum impact properties for a given carbon equivalent.

On the other hand, gray cast irons described by the lower line of the tensile strength-carbon equivalent band may be expected to exhibit excessive chilling tendencies, lower impact properties, less desirable machining characteristics, and lower resistance to galling and scratching for a given carbon equivalent.

Tensile Strength to Brinell Hardness Ratio. A common method of specifying the physical and mechanical properties of gray cast iron is by Brinell hardness number; the assumption being that the tensile strength is roughly proportional to Brinell hardness and can be calculated by simply multiplying the Brinell hardness by an empirical factor. In most cases this factor is 200, although there are instances where factors of lower values are being utilized.

The ratio of tensile strength to Brinell hardness for gray cast iron, unfortunately, is not a constant but is affected by variables associated with microstructure, etc., that generally reflect more upon one property than upon the other. The ratios for the irons studied in this series are included in Table 1. They vary from as low as 120 to 1 to as high as 234 to 1.

Apparently, the value for the ratio varies with chemical composition, becoming smaller as the carbon equivalent increases. In Fig. 4, the relation between the ratio and carbon equivalent is presented graphically, using as the carbon equivalent, carbon plus 1/3 silicon (C + 1/3 Si).

Figure 5 contains the same information, but expressing the carbon equivalent as carbon plus 1/3 silicon plus 1/3 phosphorus (C + 1/3 Si + 1/3 P). Since the use of a value for phosphorus in the carbon equivalent formula appears to increase the scatter of results rather than to narrow it, the simple expression C + 1/3 Si, shown in Fig. 4, is used subsequently in this paper.

The same technique used in plotting the curves of Figs. 1, 2 and 3 is employed in Figs. 4 and 5 for designating treatments of the irons. In these figures, however, the lower boundary of the zone for inoculated irons is the same as for the uninoculated irons. Therefore, the center line defines the maximum for the uninoculated irons rather than the minimum values for the inoculated irons.

Although the graphs of Fig. 4 indicate that the tensile strength-Brinell hardness ratio is a function of composition (C + 1/3 Si), a wide range of ratio values exist for the same given carbon equivalent. This is particularly true in the lower carbon equivalent or "hard iron" range. The spread in ratio values for the lower carbon equivalent irons is significant as an indication of structure and physical properties other than tensile strength and Brinell hardness.

The relationship between the tensile strength, Brinell hardness, and

Table 3

RELATIONSHIP BETWEEN STRUCTURE AND TENSILE STRENGTH TO BRINELL HARDNESS RATIO—LISTED BY COMPOSITION RANGE

Carbon Equivalent, per cent	*Tensile Strength Divided by Brinell Hardness*	*Structure*
3.45-3.65	210 and over	Smallest cell, normal graphite
	190-210	Small cell, normal graphite
	180-190	Medium cell, some "Type D"* graphite
	170-180	Large cell, some "Type D"—medium cell, completely "Type D"
	160-170	Large cell, partial "Type D"
	160 and below	Large cell, complete "Type D"
3.65-3.85	210 and over**	Smallest cell, normal graphite
	190-210	Smallest cell, normal graphite
	180-190	Medium cell, normal graphite or small cell, partial "Type D"
	170-180	Large to medium cell with partial "Type D" graphite
	160-170	Large cell, "Type D" graphite or free ferrite
3.85-4.20	190-210	Medium cell, normal graphite
	180-190	Medium cell, large normal graphite
	170-180	Medium or large cell, some "Type D"
	160-170	Large cell, "Type D" graphite
	160 or below	Free ferrite, "Type D" graphite

*"Type D" graphite—A.F.A.-A.S.T.M. graphite flake size chart—also called modified, eutectiform, dendritic, pseudo-eutectic, etc. Undesirable for wear resistance; low deflection, low toughness values, and poor transverse properties.
**Very few irons in this range.

the structure of gray cast iron was described by Adams[1] in 1942. Adams presented information on the cell size, graphite size and distribution, and composition of irons of various physical and mechanical properties. He attempted to classify these irons on the basis of their cell size, graphite size, graphite type, and graphite distribution.

A written discussion, presented by R. G. McElwee and T. E. Barlow,[1] attempted to correlate the same data on the basis of the tensile strength-Brinell hardness ratio. The discussion included the information shown in Table 2.

This table may be modified by the inclusion of the effect of chemical composition as indicated in Fig. 4. On this basis, the relationship between the tensile strength-Brinell hardness ratio and the microstructure is tabulated in Table 3.

Structure Type

The relationship indicated in Fig. 4 confirms the experimental information presented by Adams[1] in spite of the fact that the approach to the problem was different. Furthermore, an interesting agreement exists between the shaded areas of Fig. 4 and the change in the type of structure as indicated in Table 3.

For example, the center line of Fig. 4 passes through the points listed in Table 3 as the limiting ratios for completely normal-graphite distribution. Thus, in the lower carbon equivalent irons (3.45-3.65 per cent), those irons having a ratio of 190 or greater show normal graphite distribution with variation only in cell size and graphite size (the higher the ratio the smaller the cell size and the more refined the graphite flake).

Of those irons having a ratio of less than 190, all contained some "Type D" or modified graphite in their microstructures. Therefore, the value for the tensile strength-Brinell hardness ratio within a given range of carbon equivalent is a function of cell size, graphite size, and the percentages of "Type D" graphite structures present in the test bar; the lower values indicate the larger cell size and the greater percentage of the undesirable "Type D" graphite structures present.

Within the composition range 3.65 to 3.80 per cent carbon equivalent, relatively few irons have a tensile strength-Brinell hardness ratio of 210 or greater. Most of the irons containing normal graphite structures and extremely small cell size have a ratio in the range of 190 to 210. Therefore, in this composition range, the maximum ratio obtained is limited by composition as well as structural considerations.

Of the higher carbon equivalent irons studied, the difference between maximum and minimum ratios obtained are a function of structure. Although the variations are less pronounced in this range, cell size is restricted by composition and cooling rate, and the amount of "Type D" graphite is reflected in lower ratio values.

However, ratio values as low as 120 in high carbon equivalent irons do not necessarily indicate that they contain "Type D" graphite, since in this case the high carbon and silicon content promotes the formation of free ferrite in the 1.2-in. test bar. The presence of ferrite accounts for the low ratios obtained in the irons of high carbon equivalent values, the effect of graphite distribution and cell size merely controlling the relative position within the shaded area of Fig. 4.

Conclusions

Since both published and unpublished information confirms the relationships indicated in this paper, the following observations can be made:

1. In the absence of alloying elements, the tensile strength of gray cast iron in a 1.2-in. arbitration bar is a function of composition expressed as total carbon plus 1/3 silicon or the carbon equivalent.

2. Graphical presentation of the relationship between tensile strength and carbon equivalent may be utilized to advantage to indicate the relative quality of gray cast iron and to provide the engineer with an indication of machinability, wear resistance, and other essential engineering characteristics.

3. Dividing the value for tensile strength by the Brinell hardness number gives a value which is a function of the carbon equivalent (carbon plus 1/3 silicon).

4. The ratio of tensile strength to Brinell hardness for any given chemical composition is also a function of the structure of cast iron as indicated by the cell size, the graphite structure, distribution of the graphite, and the character of the matrix.

5. If the value for the tensile strength divided by Brinell hardness number is known for an iron of any given carbon equivalent, the relative quality of that iron is indicated by its position on a curve relating the ratio and the carbon equivalent.

6. High values for the tensile strength-Brinell hardness ratio indicate small cell size, refined graphite particles, normal graphite distribution, and relative freedom from ferrite. Conversely, low ratios with a given carbon equivalent indicate large cell size, large graphite flakes, modified or "Type D" graphite structure, or the presence of ferrite resulting either from modification or structure or from composition. Such latter irons can be expected to provide mediocre wear resistance, low deflection values, low impact strength, and low transverse properties.

7. The Brinell hardness number of gray cast iron is an indication of machinability only when the carbon equivalent is known, since a low tensile strength-Brinell hardness ratio may be the limiting factor.

8. In cases where both the tensile strength and the Brinell hardness number must be specified, their ratio should be compatible with respect to chemical composition and the type of structure obtainable.

Acknowledgment

The authors wish to acknowledge the cooperation of the Gray Iron Research Institute, Inc., which has so generously permitted the use of information obtained from foundries within its organization.

Reference

[1] Robert R. Adams, "Cast Iron Strength vs. Structure," TRANSACTIONS, American Foundrymen's Association, vol. 50, pp. 1063-1103 (1942).

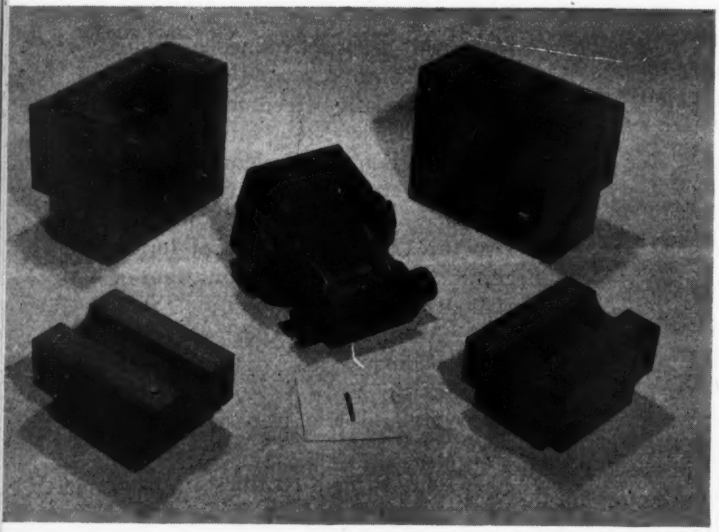
Investment Firm Acquires Interest in Equipment Co.

A SUBSTANTIAL interest in American Foundry Equipment Co., Mishawaka, Ind., has been acquired by First York Corp. and Utility Equities Corp., New York. This was announced by Otto A. Pfaff, president, American Foundry Equipment Co.

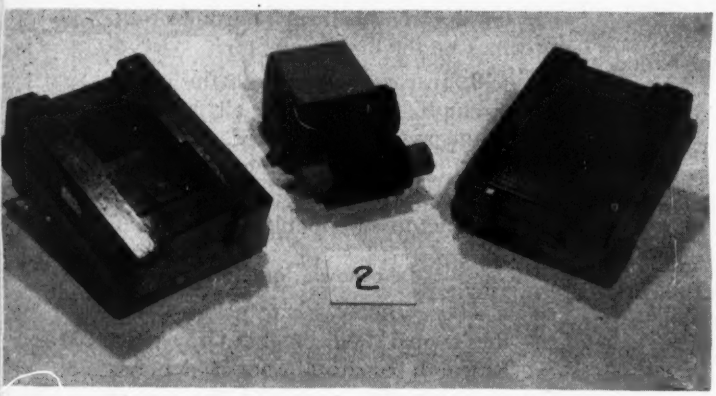
1944 PATTERNMAKING CONTEST

• Learn by doing — the basic principle of the apprentice system. The annual A.F.A. "Apprentice Patternmaking Contest" provides an opportunity for constructive criticism by oustanding men in the field — for observing the work of others — invaluable aids to the apprentice in his efforts to master his craft.

By Frank C. Cech,
Head of Patternmaking Division,
Cleveland Trade School, Cleveland,
and
Chairman, Patternmaking Division,
American Foundrymen's Association

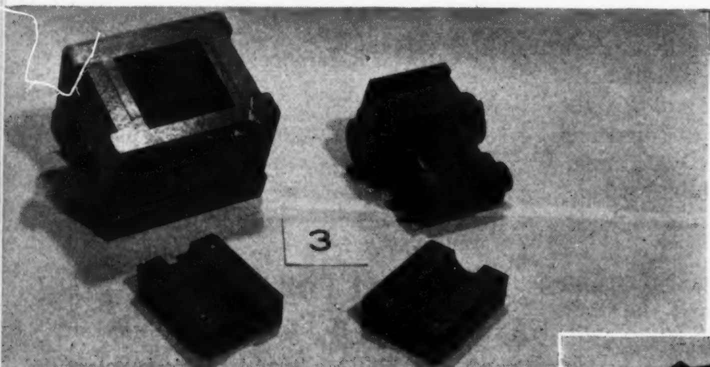


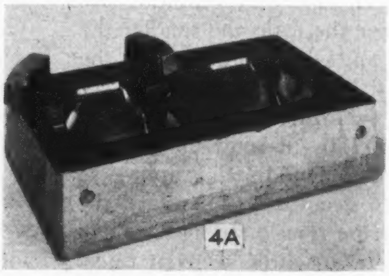
THE 1944 patternmaking contest keenly reflected the effect that the war has had on apprenticeship programs. The number of pattern entries of this year, as compared to pre-war years, looked pitifully small. However, this was to be expected and held no surprise for those who regularly follow the annual contests held by the A.F.A.

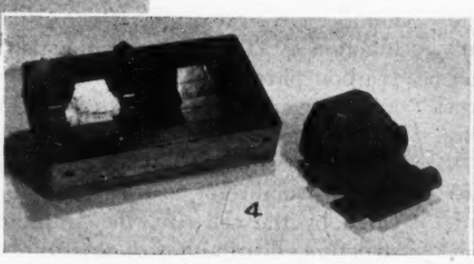


The surprise came in the variety of methods used in the choice of moldability and pattern and corebox construction that were included in the few contest projects submitted. What is the reason for this variety of choice? Is it due to the judgment of the contestant? To have judgment one must have had experiences from which to form his opinions. The apprentice, being an immature craftsman, probably has few (by comparison with a full-fledged tradesman) of these to draw upon.

Is it the careful observation by the apprentice of methods employed by those whom he assists in constructing patterns? If so, he must have a memory which readily records and retains these observations for







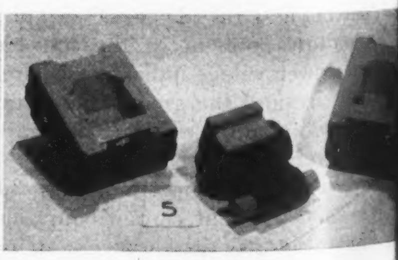
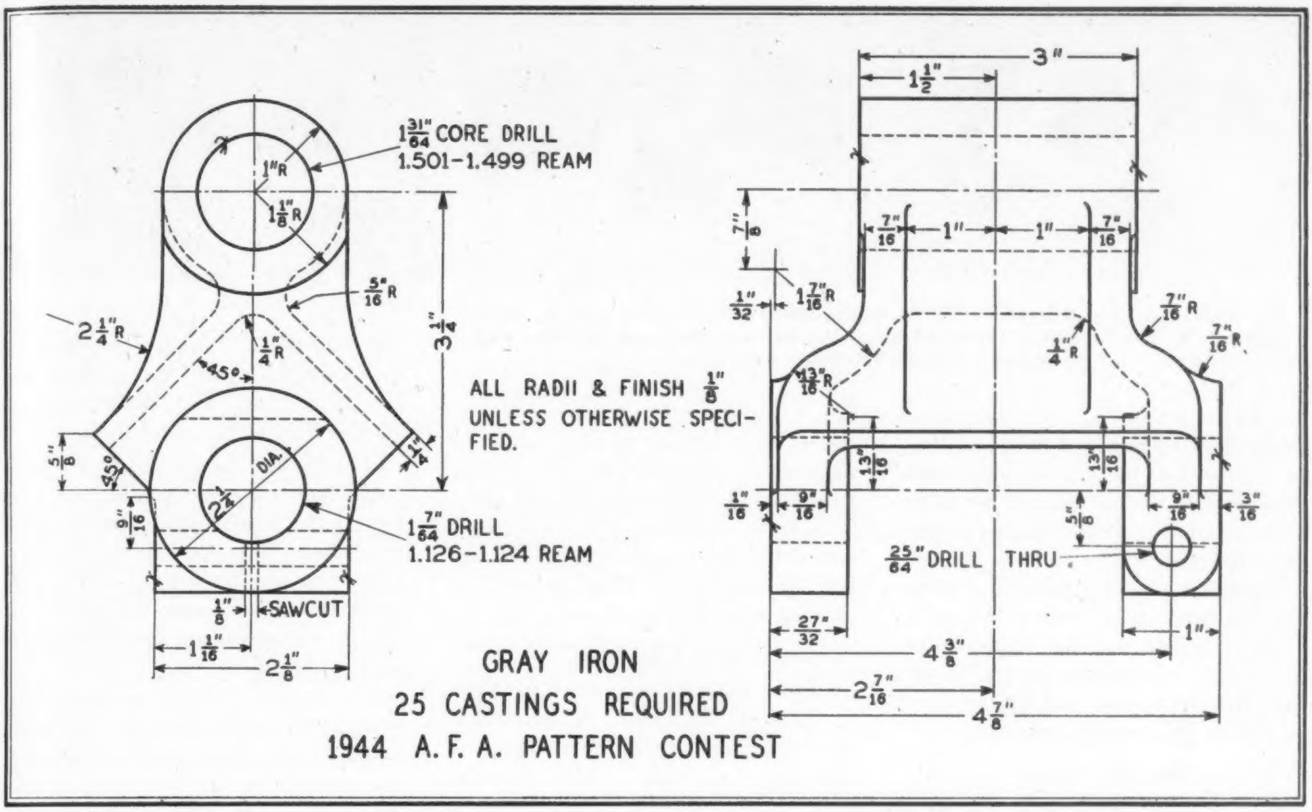


Fig. 1—Best of the entries. Corebox is full, split, dump type. Fig. 2—Split pattern and half dump corebox. Fig. 3—Full dump corebox. Coreprint is oversize. Figs. 4 and 4A—Views of gang box for two cores. Fig. 5—Split pattern and half dump corebox.



Working drawing for 1944 Apprentice Patternmaking Contest.

future consideration and use in practice of his craft.

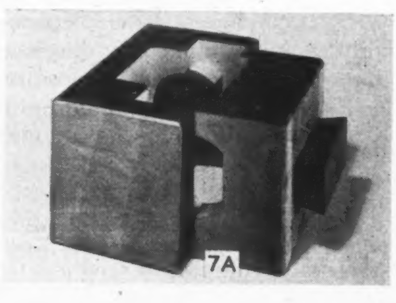
Or is it a power of analysis, inborn or acquired, which seems to be a part of all successful patternmakers and kindred craftsmen. That certain something which enables one to divide and subdivide a problem into smaller and more easily considered component parts.

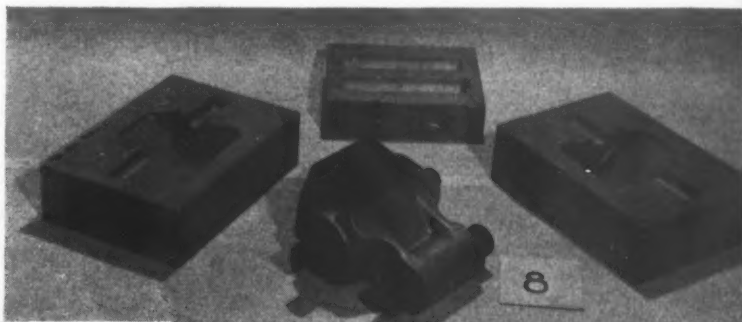
If we carefully weigh these questions we may arrive at certain qualifications that make for a good craftsman, and consequently can look for these characteristics in future apprentices.

The contest blueprint, true to type, had one dimension which did not tally with a directly related dimension, and made necessary some checking on the part of the contestant to ascertain which was correct. The term "core drill" is one that is not universally used and was confusing to some of those participating in the contest.

After studying the blueprint and observing the note "25 castings required," all contestants decided that there was only one logical way in which to make the pattern, and that was a split or parted pattern. But when it came to the moldability, involving the making of coreprints and coreboxes, that was a different story.

Figures 2, 5, 6, 8, and 10 show examples of the orthodox method of making a pattern and corebox, i. e., split patterns having all coreboxes made as half dump boxes. Figure 10 varies in that the core is split vertically and eliminates the loose pieces forming the boss, and Fig. 8 in that it incorporates a pin core within the half boxes, necessitating a loose piece draw with a





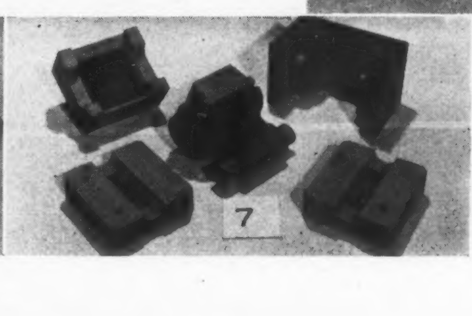
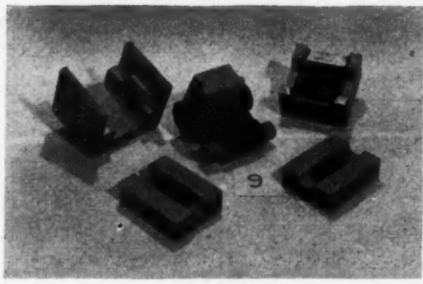
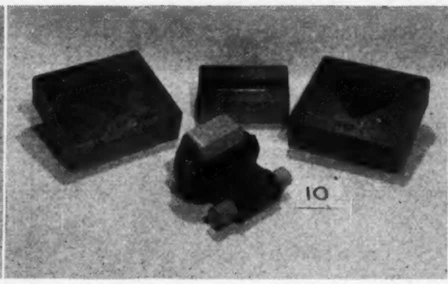


Fig. 6—Orthodox method, split pattern and half dump corebox. Figs. 7 and 7A—Split corebox, an unusual method of construction. Note grain structure shown in Fig. 7A. Fig. 8—Another example of split pattern and half dump corebox. Note pin within the half boxes.





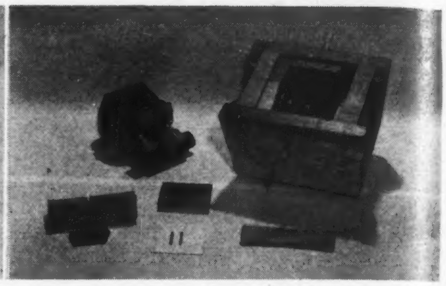


Fig. 9—Example of split corebox. Fig. 10—Split pattern and half dump corebox. Note that core is split vertically. Fig. 11—Type of construction often used for larger work of limited run. Note numerous loose pieces.

backward and upward motion. Figures 5 and 6 show a locking core provision or stop in use on the drag half, a practice of which the judges heartily approved.

Figures 4 and 4A present a gang box for two cores. They represent a well-made job, the only criticism of the judges being the objection to the use of a stock core and the absence of a stop or locking coreprint.

Winning Pattern

The corebox and pattern shown in Fig. 1 was ruled the best of the lot. The workmanship was excellent, coreboxes were reinforced, accuracy good. The corebox was a full, split, dump type, the loose pieces of which could have been improved by the use of a dovetail instead of plain anchor pieces to hold the pieces securely while ramming the core.

The pattern shown in Fig. 3 was ruled to have an oversize coreprint, too short to properly support the pin core. The core was made in a full dump-type corebox.

Careful scrutiny of Fig. 11 is necessary to appreciate the construction of the corebox. The judges' verdict was that the numerous loose pieces would produce an inaccurate core. The accuracy of dimension was good. This type of construction is popular for larger work of a limited run pattern.

The loose piece to the right of the figure "11" is a sweep used to produce the tapered or drafted ends of the core. The use of such a sweep necessitates bedding-in to get a straight resting surface for the core. This taper on some of the coreboxes submitted was ignored, as the taper left off acted as a shaving strip or clearance in the cope.

Split Coreboxes

The coreboxes included in Figs. 7, 7A and 9 present a departure from the customary procedure of making a corebox. The thought given to the splitting of the corebox is unique and probably original. One of these pattern equipments was more accurate than the others, and consequently was brought in for more consideration by the judges.

The parting of the corebox left a surface too small for the core to rest upon, and caused an overhang that might drop off or tend to overturn the core in drying. The grain structure so plainly seen in the picture causes one to wonder if the corebox halves would stick if moisture were to be absorbed.

The report of the judges on the patterns and coreboxes shown in Figs. 12, 13 and 13A was that the dimensional accuracy was OK, workmanship fair, and moldability poor. The method of construction was such that two sets of loose pieces had to be made, one each for cope and drag halves. This creates the additional foundry problem of carefully setting up the corebox for the next core, and often requires the services of a patternmaker.

The writer does not know where these patterns were made, but past experience leads him to believe that the contestants probably are employed in a pattern shop where patterns of a short run are made, or where the prevailing pattern work is of a large type.

Coreboxes of large patterns are generally constructed of box-type frames with pieces inset to give the required shape, the thickness usually being made up of a single thickness of board to which are added strips cut to width to make up the required, and generally large, overall thicknesses, as shown on loose pieces in Fig. 13A.

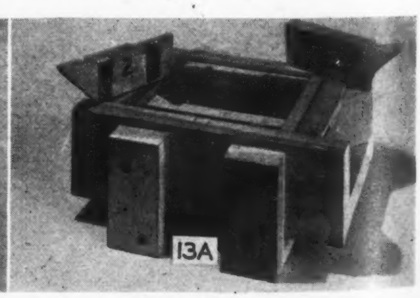
Figures 1, 2, 3 and 4 show the prize winning patterns. Because of war restrictions, it was impossible to have castings made from the patterns entered in the contest.

Pattern Discrepancies

Discrepancies found in the patterns submitted are listed by the judges as follows:

Inaccuracy of dimension; center lines omitted from the patterns and coreboxes; loose pieces resulting in inaccurate cores; dimensional differences between coreprints and coreboxes which would result in fins; oversize coreprints resulting in out-

Figs. 12, 13 and 13A—Patterns and coreboxes judged to have poor moldability features. Method of construction necessitates two sets of loose pieces, one each for cope and drag halves, requiring care in setting up the corebox.



of-round or not centrally located holes; sticking dowel pins; lack of core stops or keys for locking cores in place; coreprints too short to properly support cores; back-draft; coreboxes made in such a way as to have insufficient surface on which to rest the cores and with no possibility of bedding to brace them; and construction of the pattern and coreboxes not in keeping with the type or size of work represented by the contest part.

To one who reads the discussions of the patterns and coreboxes submitted annually in these contests, many of the discrepancies may be found repeating themselves. From this may be drawn the conclusion that little is learned by the contestants. However, it should be remembered that each year new apprentices take part in these contests, and so are apt to make the same mistakes that were made by the earlier contestants. It is hoped that the foremen and instructors of these apprentices see these reports and bring to the attention of the apprentice the mistakes he has made so that he may profit by them.

The patternmaking contest judging, held in connection with the 48th annual meeting of A.F.A., Buffalo, N. Y., April 25 to 28, 1944, was arranged by Henry Winte, Worthington Pump & Machinery Corp. The judges, all associated with Buffalo concerns, included Harry G. Ekdahl, Economy Pattern Works; Fred J. Hendler, Aero Pattern Works; Albert Amann, Acme Steel and Malleable Co.; John Franks and Erwin Deutschlander, Worthington Pump & Machinery Corp.

Acknowledgment

The committee wishes to acknowledge the courtesy of Carl W. Wade, Chairman, Apprentice Training Committee, and Caterpillar Tractor Co., Peoria, Ill., in providing the photographs of the patterns.

• COMMITTEE REPORT

PATTERN COMMITTEE

Aims to Stimulate Pattern Interest

By Chairman Frank C. Cech, Cleveland Trade School, Cleveland, and
Vice-Chairman Vincent J. Sedlon, Master Pattern Co., Cleveland

THE activities of this division may be placed respectively under the headings "industrial" and "educational," depending upon the type of activity being described.

Industrial

Foremost in the industrial section are the technical papers submitted at the patternmaking session conducted during the annual conventions. This year, at the Government's request, the convention was cancelled, but the papers will appear in the AMERICAN FOUNDRYMAN. The two papers submitted for publication are "Patterns as the Jobbing Foundryman Sees Them" and "A Pattern Analysis for Buyers."

Probably the next item of importance, and little known to Association members, is the service of answering questions that regard the patternmaking and foundry fields. The subjects of these questions covers such items as: pattern storage; pattern insurance; the availability, probable quality, and use of pattern supplies; materials and equipment; and the specific methods employed in pattern and core box construction. Questions have been received from Canada, as well as the United States.

A survey was made to ascertain to what extent A.F.A. chapters are active in sponsoring allied patternmaking divisions and promoting programs to bring foundry problems before the pattern men. The survey also attempted to determine the availability of speakers on kindred subjects. After the summer adjournment of the chapters, the incompleted survey will continue. So far, little attention has been given to patternmaking by chapters. However, there are two notable exceptions; first, the well-planned meetings of the Wisconsin chapter's Patternmaking Committee held in conjunction with the chapter's annual regional conference, and second, the meetings of the Patternmaking Groups of the Associated Industries of Cleveland and the Northeastern Ohio chapter. Some of the chapters devote one patternmaking meeting annually, others no time at all.

Following the suggestion received at the meeting of the Executive Board at the 1944 convention, an attempt was made to bring together the vendors of pattern supplies and material. However, little interest was shown and consequently no concerted action was taken on the establishment of committees for the Standardization of Pattern Supplies and Development of Standards and Simplification of Pattern Materials.

Publicity was issued to draft boards, the War Labor Board and to the public, through the press, to acquaint and enlighten them with the importance of patternmaking and licity advised a reduction in the its relative rank within the manufacturing industries. Also, the pub-

(Concluded on Page 72)

Two progressive patternmaking groups are the Pattern Manufacturers of the Associated Industries of Cleveland and (insert) Wisconsin chapter's Patternmaking Committee.

• A report of an investigation conducted under the direction of the A.F.A. Committee on Physical Properties of Foundry Sands at Elevated Temperatures, Subcommittee on Physical Properties of Steel Foundry Sands—reproducibility of hot compressive strength values when using two different type cylindrical specimen tubes.

SPLIT TYPE SPECIMEN TUBE

for Elevated Temperature Sand Testing

By D. C. Williams, A.F.A. Sand Research Fellow,
Cornell University, Ithaca, N. Y.

THE purpose of this report is to show some of the advantages of using a split specimen tube in forming a test specimen for the hot compressive strength from foundry sand mixtures. This work was authorized by the subcommittee of Subcommittee 6b7[1].

Twenty-three hundred hot compressive strength tests have been conducted at Cornell University, using (1) the usual one-piece specimen tube and (2) a split specimen tube (Fig. 1) for the molding of the 1⅛x2-in. test specimen. All of the work reported here has reference only to the molding of a cylindrical test specimen.

The reproducibility of test values is regarded from the viewpoint of tolerance limits for acceptable test values. Until more information is available regarding these limits, it is considered that any tolerance limits greater than plus or minus 5 per cent (hereafter referred to by the symbol α) from the arithmetic mean value (hereafter referred to by the symbol $\overline{X}$) would permit only a qualitative examination of the test results.

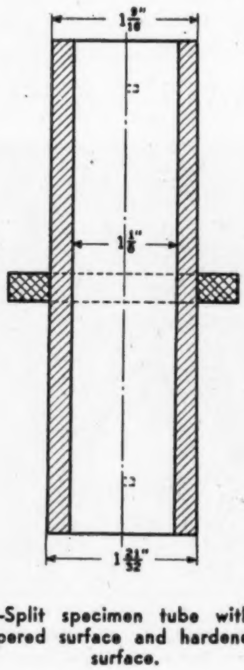


Fig. 1—Split specimen tube with sliding ring, tapered surface and hardened inside surface.

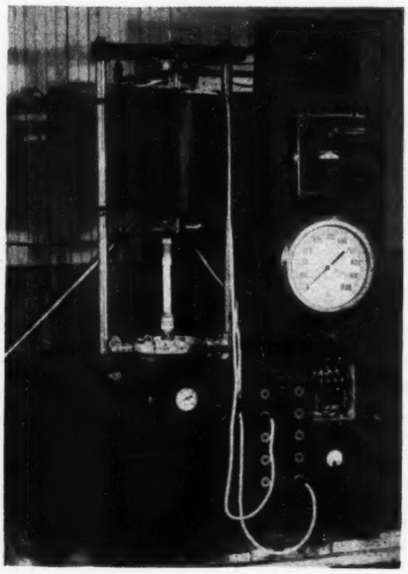


Fig. 2—Commercial equipment used in the elevated temperature sand tests.

Up until the time when studies using the split specimen tube were begun, about 45 per cent of the test values obtained at Cornell University fell within the limits of $\overline{X} + \alpha$. However, most of these tests were made with the customary discs of 5/16-in. thickness. All tests reported here were made with discs of 1⅜-in. diameter and 1-in. thickness.

Testing Equipment

Figure 2 shows the commercial testing equipment used. Two departures from the usual testing procedure for this equipment were made and are as follows:

1. Change to different discs as mentioned previously.

2. A double bore fused quartz clear tube was used to protect the thermocouple wires. Better temperature control resulted from using this type of protecting shield. The tube appeared to devitrify without causing a noticeable change in temperature control of the furnace. Vollrath[2] also found a clear protecting shield superior to others, and also notes that devitrification occurred with little effect upon temperature control.

The thermocouple supporting block was transferred to the top cross bar for convenience of inspecting and changing the thermocouple.

Sand Mixtures. The eight sand mixtures used in this investigation

Table 1

SAND MIXTURES

Mixture No.	*Component*	*Per Cent*
1	Western Bentonite	4
	Sand	96
2	Western Bentonite	4
	Silica Flour	10
	Sand	86
3	Western Bentonite	4
	Cereal Flour	1
	Sand	95
4	Southern Bentonite	4
	Sand	96
5	Southern Bentonite	4
	Silica Flour	10
	Sand	86
6	Southern Bentonite	4
	Cereal Flour	1
	Sand	95
7	Fire Clay	4
	Sand	96
8	Fire Clay	4
	Cereal Flour	1
	Sand	95

Table 2

MECHANICAL ANALYSIS

U. S. Bureau of Standards Sieve Number	*Retained, per cent*
40	0.51
50	10.15
70	40.95
100	35.40
140	10.90
200	1.92
270	Trace
Pan	Trace
Total	99.83

are listed in Table 1. Six batches from each mixture (48 batches in all) were made. The moisture content for all batches was held to 5.2 per cent ± 0.2 per cent. The washed and dried sand had the mechanical analysis shown in Table 2.

Testing Procedure. Testing was conducted at manual temperature

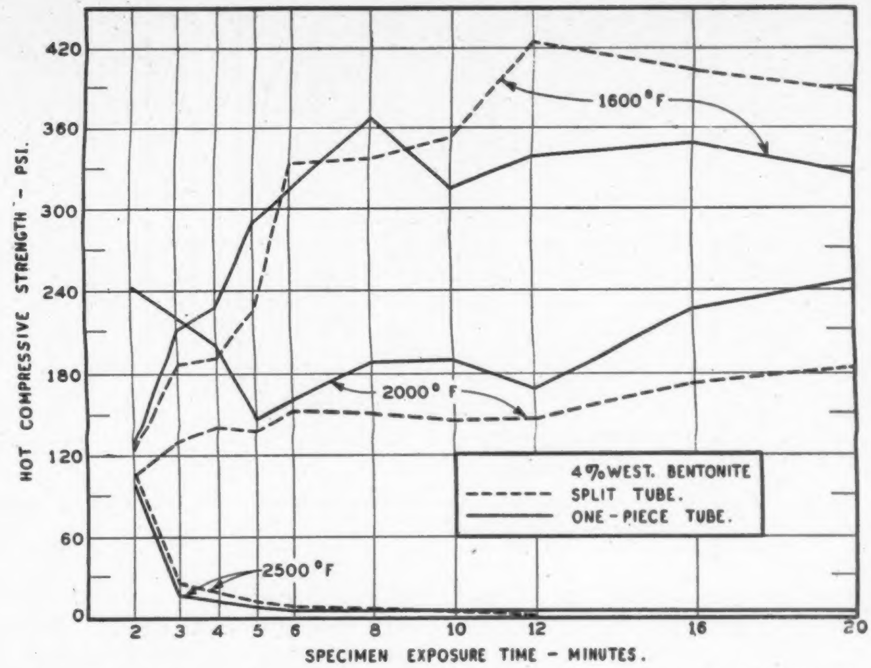


Fig. 3—Hot compressive strength values of green sand specimens made in split and 1-piece specimen tubes* from sand mixture containing 4 per cent western bentonite and 5 per cent moisture.

*Figures 4 to 10 show comparative hot strength values of specimens made in the two types of specimen tubes from various sand mixtures, all mixtures containing 5 per cent moisture.

Table 3

NUMBER OF TEST VALUES WHICH FALL WITHIN LIMITS OF $\overline{X} \pm \alpha$

(WHERE α = 5 PER CENT OF $\overline{X}$ AVERAGE)

Material added to No. 60 N. J. Sand	*Western Bentonite*		*Western Bentonite, Silica Flour*		*Western Bentonite, Cereal*		*Southern Bentonite*		*Southern Bentonite, Silica Flour*		*Southern Bentonite, Cereal*		*Fire Clay*		*Fire Clay, Cereal*		*Percentage of No. of Tests within $\overline{X} \pm \alpha$ for Exposure Time*
Temperature Control Setting, ° F.	*1600*	*2000*	*1600*	*2000*	*1600*	*2000*	*1600*	*2000*	*1600*	*2000*	*1600*	*2000*	*1600*	*2000*	*1600*	*2000*	
WITH SPLIT SPECIMEN TUBE																	
Specimen Exposure Time, min.																	
2	1	5	4	3	3	4	1	2	3	1	2	4	2	1	3	1	50
3	5	2	4	4	5	4	1	2	2	5	2	1	2	1	1	1	52.5
4	3	2	4	5	3	3	2	2	3	....	2	1	2	2	1	1	45
5	2	3	4	4	5	3	2	4	5	3	4	....	2	....	2	3	57.5
6	5	2	4	5	2	3	2	2	5	....	2	3	....	2	3	4	48.5
8	4	4	1	1	2	5	2	....	1	2	1	2	2	4	1	5	46
10	5	5	3	5	5	5	3	1	5	3	....	....	2	1	2	3	60
12	4	4	5	3	4	5	4	3	4	3	2	1	2	2	....	5	63.5
16	5	5	3	5	3	3	4	4	4	2	3	4	2	3	2	5	71
20	3	5	4	4	3	5	5	4	3	1	4	2	3	2	1	5	67.5
Percentage of 50 tests within $\overline{X} \pm \alpha$	74	74	72	74	70	80	52	48	70	40	44	36	38	37	32	66	
WITH ONE-PIECE SPECIMEN TUBE																	
Specimen Exposure Time, min.																	
2	2	1	1	2	4	4	1	....	4	5	1	1			1	4	44
3	2	2	5	3	2	5	4	3	4	5	1	3			3	....	60
4	1	3	4	1	2	1	....	1	2	1	2	4			4	2	40
5	1	1	4	3	2	3	5	3	3	2	1	1			3	5	53
6	2	3	5	5	5	2	1	2	5	5	....	4			2	3	62
8	3	....	5	4	4	2	3	3	3	3	1	2			1	2	51
10	5	3	3	3	4	3	2	1	3	2	3	3			2	4	58.5
12	....	3	2	5	5	....	5	3	5	3	2	3			3	5	62
16	2	4	3	4	5	4	4	3	5	3	2	1			2	5	67
20	3	3	4	4	....	1	4	1	4	3	1	4			2	5	53
Percentage of 50 tests within $\overline{X} \pm \alpha$	44	46	72	68	66	50	60	40	76	64	28	52			46	70	

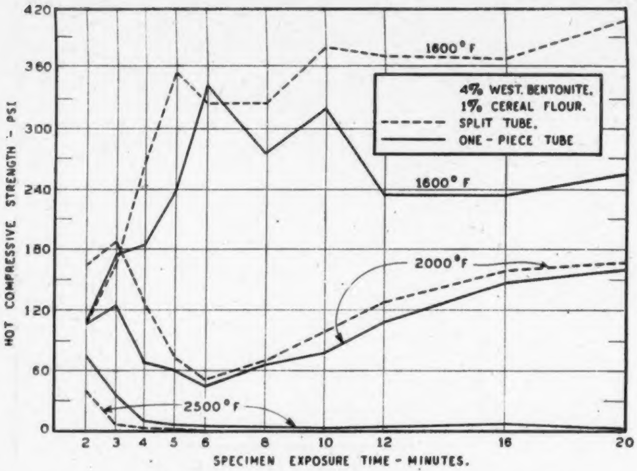


Fig. 4—Sand mixture containing 4 per cent western bentonite and 1 per cent cereal flour.

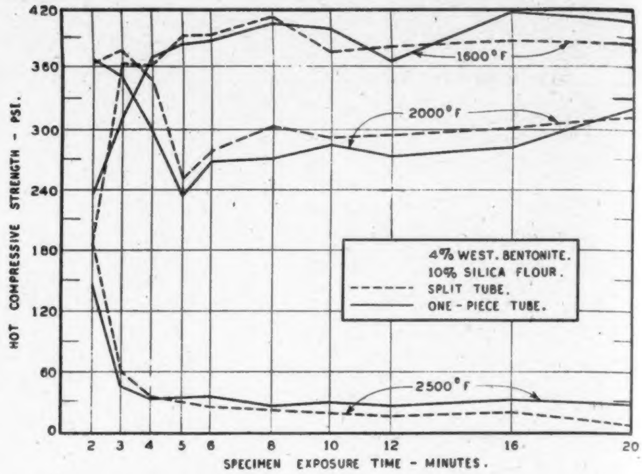


Fig. 5—Sand mixture containing 4 per cent western bentonite and 10 per cent silica flour.

control settings of 1600-2000°F. and 2500°F. After introduction of the test specimen the time required for the control point to be recovered was kept as close as possible to 2 min. and 15 sec.

The specimen exposure time includes the "recovery time" and up to the time when the upper disc and upper post made "contact," this being evidenced by a rise in gauge pressure after the tare load had been picked up. The time of exposure to heat after "contact" to maximum indicated strength averaged 30 sec., and this time is not included in the exposure time.

Five tests were made at each combination of exposure time and furnace temperature control setting. All five test values, regardless of spread of values, were used in computing the average values. In no case was a sixth test made unless a definite reason could be assigned to a discarded test value.

Comparison of Reproducibility with the Two Types of Specimen Tubes. Tolerance values were considered at temperature control settings of 1600°F. and 2000°F. At a control setting of 2500°F., a very large percentage of the test values fell below 10 psi.

Table 3 shows the results for the split and one-piece specimen tubes. Except for the right-hand column and the totals at the bottom of the table for each type of tube, the figures in each square indicate the number of tests out of five that fell within the limits of $\overline{X} \pm \alpha$.

The general average for all the tests with each type of tube indicated little difference found between the two types of tubes. However, this general average does not indicate that tests made with the split tube when western bentonite was added to the mixture were appreciably better than when made with the one-piece tube. The 4 per cent fireclay mixture gave trouble when using the one-piece tube. It was not possible to strip the specimen without damage; consequently, we have no comparison for this mixture.

During the ramming operation a "structure" is created in the test specimen. The test specimen keeps this "structure" when made in a split tube. When a one-piece tube is used the "structure" of the test specimen may be altered and the degree of alteration may depend upon the ease of stripping the specimen from the tube. The split specimen tube offers a greater chance of improving the reproducibility of test results.

Best Specimen Exposure Time. For purposes of reproducibility a specimen exposure time of 16 min. is indicated. The right-hand column for each type of tube, Fig. 3, shows the percentage of test values for each exposure time that fell within the limits of $\overline{X} \pm \alpha$. The split tube indicated 71 per cent of results within $\overline{X} \pm \alpha$ and the one-piece tube indicated 67 per cent of results within $\overline{X} \pm \alpha$.

A 4 min. exposure time indicated the least percentage of reproducible results for each type of tube. It may be noted here that for each tube the

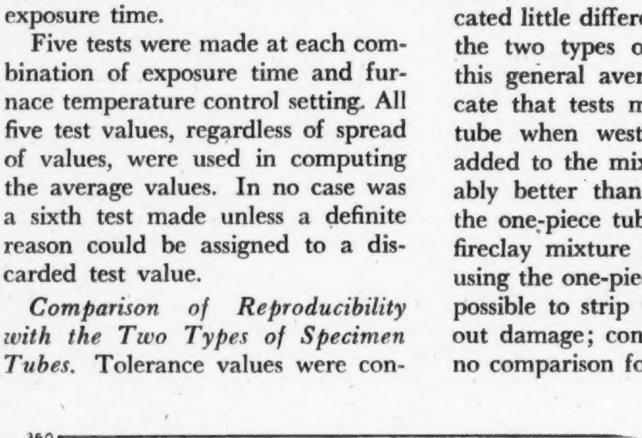
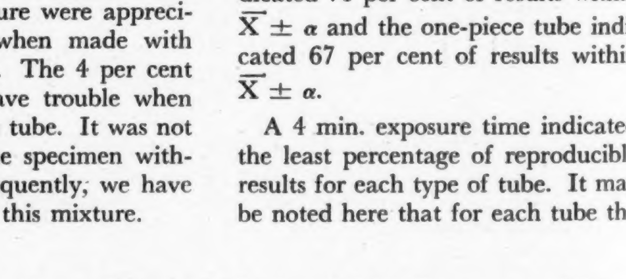


Fig. 6 (left)—Sand mixture containing 4 per cent southern bentonite.

Fig. 7 (below)—Sand mixture containing 4 per cent southern bentonite and 1 per cent cereal flour.



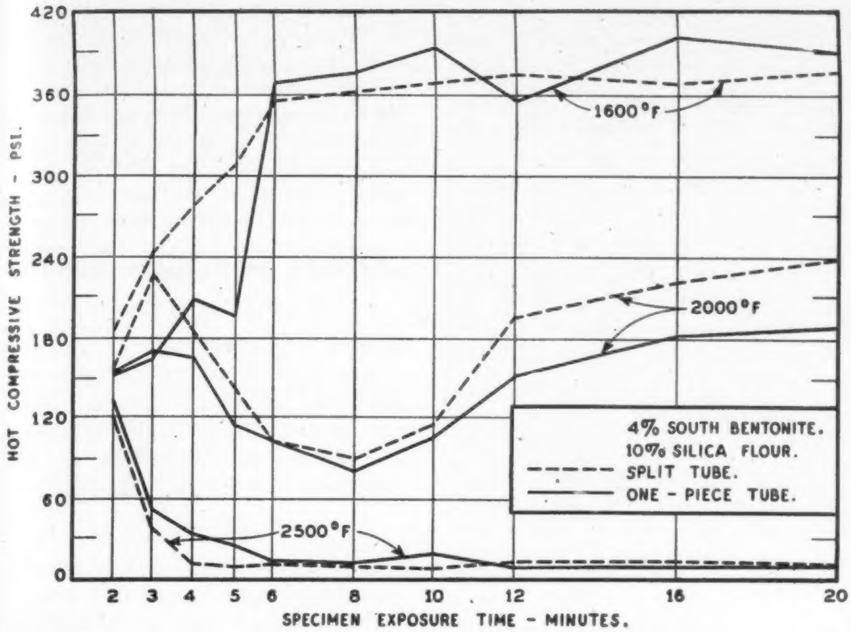


Fig. 8—Sand mixture containing 4 per cent southern bentonite and 10 per cent silica flour.

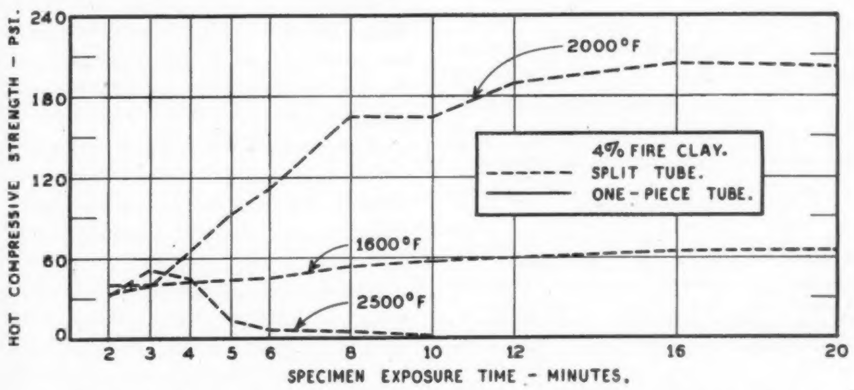


Fig. 9—Sand mixture containing 4 per cent fire clay. One-piece specimen tube could not be used with this mixture because of damage to specimen when stripping.

number of conditions of testing at which none of the tests fell within the limits of $\overline{X} \pm \alpha$ are about equal.

Comparing Sand Mixtures. It has been the usual custom to choose a certain exposure time at which all types of mixtures are compared. A certain degree of success has been found by some using this method. However, this type of comparison assumes that the test specimen is a one-piece specimen after being subjected to heat.

In the writer's Fourth Progress Report,[3] rinding and coring of the test specimen was discussed. This rinding and coring probably accounts for the test results shown in Figs. 3-10 at a specimen exposure time of 2 min. (used by several laboratories for control purposes).

It will be noticed that at an exposure time of 2 min. the hot compressive strength values at two or more of the temperature control settings were approximately the same. Because of rinding and coring of the test specimen there must have been two or three combinations of rind and core that gave similar test values. It follows that either the rind or the core will transmit the externally applied load until failure occurs.

The relative stiffnesses of the rind and core should be considered in connection with the rind and core formation. The respective core and rind areas will not be the same as the original specimen before it has been subjected to the furnace temperature. In addition, some test specimens increase in face area due to heating. It must be remembered that at present the hot compressive strength value recorded is only a *nominal value* and assumes a one-piece specimen which has not changed in face area.

Since heat penetration probably varies with exposure time and furnace temperature, it seems logical that various test specimen should be compared on the basis of equal rind and core formation.

It might be found, for example, when comparing the three mixtures containing western bentonite, that equal rind and core formation would take place at same temperature control setting as follows: 4 per cent western bentonite—exposure 6 min., 4 per cent western bentonite plus 1 per cent cereal flour—2 min., 4 per cent western bentonite plus 10 per cent silica flour—20 min.

For illustration purposes let us consider a mixture tested at three temperature control settings at 2 min. exposure. In addition, to simplify conditions, the core will be the

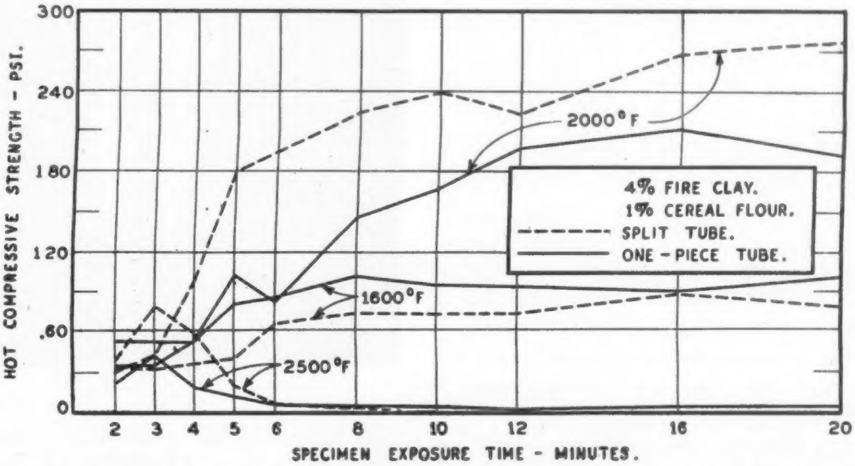


Fig. 10—Sand mixture containing 4 per cent fire clay and 1 per cent cereal flour.

only part of the test specimen which transmits the external load. In this case three combinations of rind and core yield the same value in pounds, but due to the smaller core area at the higher temperature the actual strength of a test specimen at temperature control setting of 2500° F. may be greater than the psi. at a temperature setting of 1600° F.

Accurate knowledge of furnace temperatures and rate of heat penetration into the test specimen will be necessary in order that two sand mixtures may be quantitatively compared. Since control laboratories in the foundry usually make all the comparative tests, these laboratories will have to be able to determine rates of heat transfer and have accurate knowledge of temperature distribution within their particular furnaces.

With the use of the split specimen tube, the reproducibility of certain tests averaged about 75 per cent within $\overline{X} \pm \alpha$. Since the only change in procedure was the type of tube used, which brought about a 15 per cent increase in reproducibility, it seems possible that studies on mixing and ramming might raise this reproducibility to perhaps 95 per cent of the test results within $\overline{X} \pm \alpha$.

All of the mixing was done in the same mixer with the same operating speed and rake settings. With this set-up, mixtures containing western bentonite gave the best reproducibility. It may be that this speed in rpm. of the mullers and rake settings does not give the best mixing for mixtures containing southern bentonite or fire clay. This may be one factor which accounts for the lower reproducibility of test values.

Conclusion

A split specimen tube has been found to be superior to a one-piece specimen tube for the following reasons:

1. The rammed "structure" of the test specimen is better preserved.

2. Specimens from a certain sand mixture could not be stripped from the one-piece tube without damage.

3. With specimen from sand mixtures containing western bentonite the reproducibility of test values within any one batch was consistently appreciably higher.

4. The type of split tube used in the investigation was found to be easier to use than the one-piece tube.

The best reproducibility of test values was indicated at a specimen exposure time of 16 min. This observation was found for both types of specimen tubes studied.

Since all specimens tested exhibited rinding and coring, it seems logical that the strength values of test specimens from various sand mixtures should be compared on the basis of equal rind and core formation or equal heat penetration rather than the usual equal specimen exposure time.

After the tests reported in this paper were completed, a study of the temperature-indicating equipment was conducted. It was found that the control settings gave the following:

Control Setting on Instrument, °F.	*Actual Control Temperature, °F. (Avg.)*
1600	1557
2000	1967
2500	2482

It follows that the indicated temperature is not always what appears on the control instrument. Furthermore, the error is not constant over the range of the control instrument.

References

1. "Report of Sub-Subcommittee on Rammer Supports of Subcommittee on Physical Properties of Steel Foundry Sands at Elevated Temperatures," TRANSACTIONS, American Foundrymen's Association, vol. 52, pp. 1024-1036 (1944).

2. J. P. Vollrath, "Improved Control Through Use of Transparent Thermocouple Protecting Tubes," *Industrial Heating*, pp. 1619-21 and p. 1708, Oct., 1944.

3. D. C. Williams, "Fourth Progress Report on Investigation of Physical Properties of Steel Foundry Sands at Elevated Temperatures," TRANSACTIONS, American Foundrymen's Association, vol. 52, pp. 979-1009 (1944).

Pattern Committee Report

(Continued from Page 67)

drafting of patternmakers.

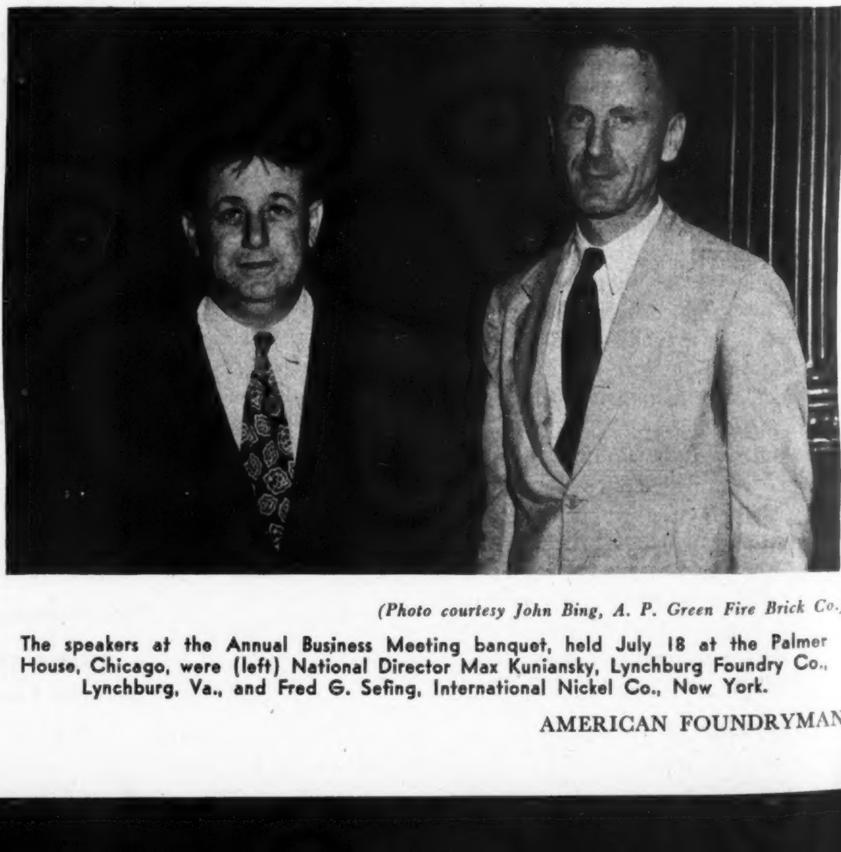
Inquiries on pattern coatings, supplies and material reveal the necessity of an unbiased, unprejudiced and deeply interested committee for trying out and testing these products.

Educational

In the educational field, there was issued a planned layout, in blueprint form, together with an identifying code and list of tools and equipment, a minimum and maximum basis for the teaching of patternmaking on a high school and trade school level. An introductory article on patternmaking accompanied the layout and listing of tools and equipment.

The annual A.F.A. apprenticeship contest in patternmaking was precluded by regional contests sponsored by local pattern manufacturers and their groups.

Field trips and open house visits were planned by some of the pattern groups to better acquaint school administrators, teachers and others with opportunities in this field.



(Photo courtesy John Bing, A. P. Green Fire Brick Co.)

The speakers at the Annual Business Meeting banquet, held July 18 at the Palmer House, Chicago, were (left) National Director Max Kuniansky, Lynchburg Foundry Co., Lynchburg, Va., and Fred G. Sefing, International Nickel Co., New York.

Post War Operations of Aluminum Foundries

Operational controls have enabled foundries in general to meet the specifications demanded for certain wartime castings. Continued rigid controls will retain the confidence of designers and result in wider postwar applications of cast metals as engineering materials. Properly organized maintenance and sales forces will have important parts in the postwar foundry.

By W. H. Gunselman,
Director of Research and
Foundry Engineer,
Samuel Greenfield Co., Inc.,
Buffalo, N. Y.

(Courtesy Caterpillar Tractor Co.)

Removing burrs from the fins of cast aluminum cylinder heads with fin grinding machines.

PRIOR to the war, development in the founding of light alloys was comparatively slow, but during the war period, especially within the past 3 or 4 years, progress has been extremely rapid. This is largely because of the demands of the aircraft, marine, automotive, and related industries, where lightness and strength are of paramount importance.

The cost of aluminum castings per unit weight is moderately high. However, the cost per piece (because of its extremely low density—only 1/3 that of bronze) often compares very favorably even with the least expensive metal, cast iron. Besides those industries in which the advantages of light castings are obvious, aluminum castings are being increasingly employed in general engineering work, particularly for reducing inertia losses or where shipping weights must be considered.

Commercial Possibilities

During the past few years, foundry practice with aluminum has changed from the manufacturing of ornamental non-functional and non-stressed components to parts used in the most intricate and exacting of machine functions in the ultimate state. In other words, formerly aluminum castings were found in such application as washing machine parts, household equipment, automotive decorative parts, and similar uses where strength, chemical compostion or other mechanical and chemical properties played absolutely no part.

Prior to the war, some small use was made of aluminum in the commercial production of automotive cylinder heads, but anyone in the smelting business who was at all observant could determine that a very large percentage of heavy scrap turned out to be these cylinder heads. This point is made to illustrate that, while there was an awakening as to the possibilities of aluminum, so little was known of its properties that successful casting and use of these properties was not accomplished.

Today, aluminum is specified for entire aircraft power plants, with the exception, of course, of the high temperature operating friction parts such as valves, pistons, rings, cylinder liners, and bearings. Blocks, heads, manifolds, coolers, cover plates, all are made from aluminum with a relatively high degree of success.

In addition, where decorative parts were formerly overdesigned because little was known of the mechanical properties of aluminum, the percentage of over-design has been greatly reduced. Safety factors of 1½ or less to 1 are now common, whereas only a few years ago safety factors as high as 4 and 5 to 1 were the accepted practice.

Value of Test Reports

As more and more is being learned, manufacturers are in a position to know exactly what alloys are to be used in making their parts, and exactly how they will behave under various operating conditions, such as temperature, corrosive atmospheres, vibrational stress, etc. Also, as a result of recent work, they are in a position to know what a foundry can and cannot do.

This explains somewhat why it is now necessary to supply physical and mechanical test results, in addition to the other paper work and laboratory work required for castings. The day when a casting could be made and shipped without the quality being known has definitely gone. Ten years ago it was permissible to make almost any type of casting out of

almost any alloy at the founder's discretion, without regard as to how that alloy performed.

This is not intended to be a criticism of this particuar method of operation, since performance requirements were not necessary and frequently were not even stated. In other words, a goodlooking, clean casting was all that was desired, and the engineers were confident enough of their overdesign to insure that even the poorest quality aluminum casting would not fail in service.

Rigid Specifications

In the war years, cast aluminum made inroads into fields formerly engineered by founders of heavier metals. Of course, this was under control, and in such a way that accumulated data and technical information are available to all founders and all customers. This has called for exacting specifications, even to the point where these specifications have been called impossible or impracticable from the founder's viewpoint.

A common belief has been expressed many times that existing specifications were only wartime measures that would be completely relaxed after the war. The author does not at all agree with this statement, and believes that postwar specifications will be even more strict. The aircraft, automotive and marine industries will continue changes inaugurated before and during the war, with a tendency toward reducing weight and increasing efficiency.

Any engineer with half a high opinion of these two points will, of course, turn to aluminum and magnesium founding industries for castings, since it would be pure folly to step backward into heavier metals and consequently reduced pay loads. Therefore, it may be stated that specifications imposed on foundries will become tighter and tighter. Therefore, it behooves all founders to try to observe existing specifications to the best of their ability in order to prepare for the future.

The only way that existing specifications and future specifications will be met is by complete and honest control of every step in the manufacturing process. It is the thought of some people in the foundry business that they may simply pour the metal and ship the casting. In addition, it is felt that, due to the type of help employed in some foundries, technical and scientific control is either difficult or out of the question.

This conception is absolutely incorrect, and the founder must attempt to start off with the idea that his industry is every bit as technical and as scientific as the manufacture of perfection intricate parts. If the founder does not realize this fact, it is more than likely that he will be out of business in the postwar period.

Controls are used not only for meeting specifications but for reducing scrap losses, consequently improving the quality of the product. This applies to highly stressed component parts, as well as to aluminum cookware.

Foundry Operations Control

Controls to be used in the foundry are not different from controls used in other industries. They must be used thoughtfully, with the idea that information gained from controls may be further elaborated upon in order to enable the foundry to produce better material at lower cost, in order to compete with other industries.

By control is meant methods and procedures in handling materials and personnel in such a way that a definite, known product may be produced every time certain operations are performed. Briefly, some of the essential procedures in handling aluminum castings in postwar foundries should include the following:

It is necessary that all raw material entering the plant, whether it be ingot metal, sand, flux, binders, core oils, etc., be under definite chemical control. There should be no question as to the composition of material charged to furnaces. This material should be handled by an easily reproducible method which insures uniform melting practice and uniform treatment of the material within the melting furnaces.

Furnace Charge Quality

In addition, automatic recording and control instruments should be installed, thus removing the responsibility of handling molten metal from the hands of workers and giving it over to the care of reliable instruments.

In the author's opinion, only analyzed ingot metal should be charged to the furnace; that all foundry returns (gates and risers and scrapped castings) should be converted into ingots before use in the pouring of castings. Fundamentally inherent problems in the handling of cast aluminum are great enough in themselves without introducing additional difficulties by the use of foundry returns in the melt.

This paper was presented before the Western New York Chapter of A.F.A., Dec. 1, 1944.

Assuming that the metal is molten, pouring practice, which includes treatment of the metal after it leaves the melting furnace and until the casting is shaken out, should be uniform and controlled.

Since the second most important raw material used in foundries is sand, it is only logical that this material should be controlled, at least as well as the metal being poured. *No matter how well and honestly the metal is handled, successful castings cannot be poured unless the sand conditions are correct.* Constant control of molding sands is absolutely essential. This should be done with reliable instruments, not by the old "hand test."

Core sand mixing procedures, type of sand, binders, type of oil, time and temperature of baking and the integrity in mixing should be known and controlled. The personnel handling the core mixtures must be absolutely reliable.

Casting Inspection

After the casting has been shaken out and cleaned, a satisfactory inspection, which should include a dimensional check and a thorough surface inspection, must be made. Spot x-ray and spot pressure test examinations should be made, even if not required by specifications.

The mere visual inspection of a casting to determine its features should not be tolerated. Complete and thorough inspection is one of the best methods the foundry has for controlling quality and detecting obvious foundry errors before they become serious enough to create a high scrap figure.

After the casting has undergone this primary inspection, it is necessary in numerous cases to heat treat the castings in order to obtain the highest ultimate physical properties

from the alloy. Heat treating is preferably available with the foundry itself. In any event, heat treatment should be controlled to the satisfaction of the foundries and under the type of control that is warranted by the properties the ultimate casting must exhibit.

Following heat treatment, a hardness test should be made to determine the efficiency of the heat treatment, as well as the physical properties, as represented by test bars of the same alloy and which underwent the same treatment cycle as did the castings involved. Following heat treatment and further cleaning, there should be a final inspection which should follow the same trend as preliminary inspection; i.e., pressure test, spot x-ray, dimensional check, etc.

Castings Reclamation

As a result of this inspection, it will be necessary for the foundry to provide methods of salvage and reclamation of castings which are rejected for very minor imperfections. Processes used in reclaiming castings must be under strict control; otherwise they become a burden rather than an additional source of income. Likewise, lack of control would tend to break down the efforts of personnel within the foundry to improve the quality of the castings.

If too many castings are permitted to be reclaimed, the feeling becomes "What's the difference, they will salvage it anyway." Processes for reclaiming castings consist generally of welding, impregnating, and shot blasting. These must definitely be followed by additional pressure tests, dimensional checks, x-ray, and any other test deemed necessary to ascertain the acceptability of the salvage operation.

Personnel Control

The foregoing paragraphs have touched remotely on some of the major items which must be controlled so that a foundry may operate successfully in the postwar picture. There is one definite control essential to this premise—that is, absolute control of personnel.

Personnel engaged in any phase of the foundry operation must be disabused of the idea that they are in a rough, dirty industry which has little or no moral control. They must be invested with a spirit of cooperation and loyalty to the foundry. They must realize that without specific cooperation, successful castings cannot be made and successful business cannot be conducted.

Wage scales must be arranged in such a way that one department does not operate for the purpose of making scrap which it knows will be salvaged by some other department. This situation has been known to exist, even though the foundry management was aware of the fact.

Cooperation Necessary

Foundry personnel must be trained to realize that electric and other methods of control and recording are not used because the honesty of the personnel is doubted, but with the idea of producing better materials.

However, even if this latter point is not made successfully, the men must be made to realize that either they cooperate in the use of such equipment or be removed from the employ of the foundry. This includes supervision and all types of personnel which operate with the idea "We made castings this way 20 years ago and we are going to continue making them the same way for the next 20 years."

The successful carrying out of many of the aforementioned steps assumes that the foundry has provided itself with reliable, high quality laboratory personnel which can successfully interpret and control these operations. They must be in a position to give unhampered service in any laboratory function.

This is admittedly an expensive item for the small foundry, appearing to the management as an expense way out of proportion to the immediate benefits derived. A small but well-equipped laboratory will pay for itself many times over if wisely used. Essential, of course, are chemical laboratory and physical testing facilities which are capable of handling sand, metal and other basic raw materials.

Laboratory Facilities

For the larger foundry, these become transformed into a chemical laboratory or a spectographic laboratory, or both; the sand laboratory, a physical testing laboratory, an x-ray laboratory and a metallurgical laboratory. These laboratories must all be in a position to operate freely as a service unit, unhampered by the demands made upon the production department.

It is not meant that they may operate in a slack fashion, but that they must be permitted to make their recommendations and analyses freely and honestly, with the knowledge that their recommendations will be accepted by the production department in good faith. This calls for complete cooperation and harmony between production and its service unit laboratory.

Two further items which play an important part in the successful operation of all foundries are the maintenance department and the sales department.

The maintenance department should be organized in such a way that equipment difficulties are recognized far in advance, preferably through a system of preventive maintenance, and foreseen difficulties are quickly and thoroughly repaired. Electricians cannot be "wire jerkers." They must be capable and thorough, with a knowledge of what they are attempting to do.

Maintenance Organization

They must be equipped with proper tools and work under supervision capable of recognizing a job well done and which will not back them in the case of poor work. In too many cases has this particular division of foundry operation been neglected to a point where controls and other wiring have become "rat's nests" of wires, which are completely unintelligible to anyone when controls or wiring fail.

Maintenance men should be capable of working from blueprints and doing the type of maintenance work that would be demanded of them in any of the more highly technical industries. Much of the maintenance now practiced in the foundries would not be tolerated in customer's machining plants.

One of the most important requirements is that the foundry should provide itself with a suitably educated sales force which is not so completely "money-hungry" that any and every type of job is taken without regard to its metallurgical demands. Much money has been lost by this failing; much money will continue to be lost unless this failing is corrected immediately.

Introspection into foundry sales

forces will doubtless reveal that many are not trained in knowing exactly what they are selling. They are not trained in the economics of foundry practice to the extent that salesmen in other industries are trained before being permitted to contact customers.

It is quite certain that, with the knowledge gained during the past several years, aluminum foundries have learned the value of control of all possible variables in operations. These controls will be further elaborated upon in postwar years to continually improve the quality, as well as the quantity, of castings produced; thus enabling aluminum to more successfully compete with heavier metals in particular fields of application. Aluminum foundry operators will see to that.

• COMMITTEE REPORT

CHEMICAL ANALYSIS

Laboratory Assists Many Foundries

By Chairman H. F. Scobie,
University of Minnesota, Minneapolis

An analytical laboratory is recognized as a necessary department of any truly modern foundry. A foundry that does not enjoy the advantages of its own laboratory is forced to rely on outside sources for its analytical control of both product and materials. Such an arrangement is unsatisfactory because the foundry invariably waits until it is in trouble before checking raw materials and finished products. Locking the door after the horse is stolen never has been considered a wise policy.

Variety of Castings

A foundry served full time by a laboratory and chemist is in a far better competitive position than one operated by rule of thumb. Buyers of castings have learned, if they did not know it before, that dependable castings can be made in a wide variety of shapes and sizes, of alloys to suit any purpose, and at reasonable cost.

Not every foundry is capable of producing every type and size of casting or every type of alloy, but those able to make the greatest variety of products within the size range that its equipment and facilities will allow, will occupy the best competitive positions. Diversification is the trend.

From the buyers' standpoint, a laboratory advertises the foundry's belief and faith in raw material and process control. It impresses the purchaser with the idea that the foundry is interested in, and capable of, consistent quality from day to day. Even mediocrity, if consistent, is more desirable than sporadic high quality.

To illustrate what chemical laboratories have done for foundries or users of castings, a number of actual instances are cited.

Example No. 1—About 10 years ago, a manufacturer operating several foundries installed a laboratory, one of the finest in the territory. The immediate and wholly unexpected result was that one-third of the purchased materials were rejected because they failed to meet the specifications set up for them.

This was not entirely the fault of the companies from which the materials were purchased. There is ample opportunity for clerical errors by the time an order has passed through numerous hands. One plant found that 2 per cent of shipments received were mislabeled. If the discrepancies had not been discovered, serious results would have been inevitable.

Discovered Ferro-Chromium

Example No. 2—Another plant discovered that it was unknowingly in possession of a supply of ferrochromium at a time when alloying agents were difficult to obtain. If a curious workman had not discovered it and taken some to the laboratory for analysis, the valuable material might never have been used.

Example No. 3—Some foundries have every type of control but chemical analysis. They have government ceilings on men, price control, labor control, production control, and a time clock to make sure that every man gets paid for the time he puts in. The only control lacking is the one that prevents wasted time and money by insuring a desired type of metal for melting and casting.

The experience of a small midwestern foundry serves to illustrate the advantage of knowing over guessing, and the fallacy of averages. The foundry regularly produced a type of iron with a minimum tensile strength of 35,000 psi. A special job, however, required several taps of ASTM Class 50 iron daily. Rather than prepare special charges, it was planned to alloy the base metal with molybdenum when a tap of the higher strength iron was required.

The average analysis of the metal was known from occasional samples which were sent to commercial laboratories for analysis. However, the strength of the test bars which were poured from the alloy iron often did not meet the minimum 50,000 psi. requirement. Analysis showed that the carbon content of these bars differed considerably from the average analysis used as a basis for figuring the alloy addition.

Discovery Made

When the plant installed a laboratory of its own and made a complete tap by tap analysis of a number of heats, it was discovered that there was a definite trend in effect from the beginning to the end of the day's run. Only during a certain period of the heat was the iron receptive to alloy additions.

The foundry had a choice of making alloy additions at the period when they would be most effective, or of adjusting the cupola practice. Choosing the latter, the foundry developed a procedure that resulted in a constant quality of iron throughout the heat.

Example No. 4—A steel foundry that long has recognized and successfully used chemical control, is the scene of another triumph for the laboratory. During a certain period of operation, there was a very gradual decline in mechanical properties. Comparison with the chemical analyses of the heats in question showed a corresponding increase in sulphur content. Suddenly several of the heats did not meet specifications and one heat had a sulphur content beyond the maximum allowable. Microscopic examination showed excessive sulphur inclusions.

A systematic examination of all

(Continued on Page 99)

NEW ASSOCIATION MEMBERS

(July 16 to August 15, 1945)

• Twenty-seven A.F.A. chapters have increased their memberships by one or more new members this past month. The total number of new memberships sent into the National Office was 81. The Northwestern Pennsylvania chapter led the parade with 13 new applications but was pushed to the limit by the Southern California chapter who enrolled 12 new members. Third place honors fell to Chicago as it contributed 7 memberships to its enrollment.

Conversion—Company to Sustaining

Joshua Hendy Iron Works, Sunnyvale, Calif. (John B. Bubb) (Northern California Chapter).
Warden King, Ltd., Montreal, Que., Canada (Eastern Canada & Newfoundland Chapter.)

Conversion—Personal to Company

The Medart Co., St. Louis, Mo. (H. Goodwin, Foundry Supt.) (St. Louis Chapter).
Knute Palmquist Brass Bronze and Aluminum Foundry, Oakland, Calif. (Knute W. Palmquist, Owner and Mgr.) (Northern California Chapter).
Smith System Foundry, Minneapolis, Minn. (Harry Hyland, Mgr.) (Twin City Chapter).
Watervliet Foundry Co., Watervliet, Mich. (W. H. Stine) (Michiana Chapter).
Foundry Supply Co., St. Paul, Minn. (Norman E. Wisner) (Twin City Chapter).

BIRMINGHAM CHAPTER

L. E. Bondurant, McWane Cast Iron Pipe Co., Birmingham.
Frank Kopp, McWane Cast Iron Pipe Co., Birmingham.
Ross Martin, Jr., Production Engr., McWane Cast Iron Pipe Co., Birmingham.
William M. Spradlin, Melting Foreman, McWane Cast Iron Pipe Co., Birmingham.

CANTON DISTRICT CHAPTER

Raymond Cox, Sales Mgr., Standard Horse Nail Corp., New Brighton, Pa.
Dale Crumley, Pattern Foreman, Pitcairn Co., Barberton, Ohio.

CENTRAL INDIANA CHAPTER

C. F. Sterling, Pres., Centrifugal Casting Co., Fort Wayne, Ind.

CENTRAL OHIO CHAPTER

W. L. Groce, Patternmaker, International Derrick & Equipment Co., Columbus.

CHESAPEAKE CHAPTER

Raymond F. Foster, Asst. to Plant Met., Lynchburg Foundry Co., Lynchburg, Va.
Henry D. House, Procurement Mgr., Doughnut Corp. of America, Ellicott City, Md.
R. M. Stickley, Jr., Norfolk & Western Railway Co., Roanoke, Va.

CHICAGO CHAPTER

Carl H. Burton, Sec., Aluminum Research Institute, Chicago.
Doane K. Hollins, Salesman, National Engineering Co., Chicago.
***Imperial Belting Co., Chicago (Zell F. Harshton, Vice-Pres.).**
John W. Lohnes, Dist. Sales Mgr., Vanadium Corp. of America, Chicago.
Allan S. Noyes, Div. Tech. Mgr., Foundry Rubber Compounds Corp., Chicago.
Kermit A. Skeie, Met., Howard Foundry Co., Chicago.
Laurance E. Wallace, Sales Engr., American Steel Foundries, East Chicago, Ind.

CINCINNATI DISTRICT CHAPTER

A. H. Layford, National Cash Register Co., Dayton, Ohio.

DETROIT CHAPTER

Ray E. Bailey, Service Engr., Ingersoll-Rand Co., Detroit.
John M. Howard, Student, General Motors Institute, Flint, Mich.

EASTERN CANADA & NEWFOUNDLAND CHAPTER

Jos. Fournier, Mill Supt., Dominion Arsenal, St. Malo, Que., Canada.

METROPOLITAN CHAPTER

Angelo Di Leo, Foundry Supt., Bound Brook Oil-Less Bearing Co., Middlesex, N. J.
***Eastern Metal Products Co., Tuckahoe, N. Y. (Seymour Troy).**

MICHIANA CHAPTER

Alex Bohle, Foreman, Watervliet Foundry Co., Watervliet, Mich.
Louis F. Brady, Foreman, Watervliet Foundry Co., Watervliet, Mich.

NORTHEASTERN OHIO CHAPTER

R. D. Hulslander, Owner, Aimes Engineering Co., Cleveland.

*Company Member.

NORTHERN CALIFORNIA CHAPTER

George A. Shaw, Asst. Mgr., Knute Palmquist Brass Bronze and Aluminum Foundry, Oakland, Calif.

NORTHWESTERN PENNSYLVANIA CHAPTER

Ray G. Bliley, Foreman, Soft Iron Cleaning, General Electric Co., Erie, Pa.
Edward J. Dworakowski, Foreman, Malleable Melting, General Electric Co., Erie, Pa.
Stephen Engel, Foreman, Core Room, General Electric Co., Erie.
Chester H. Gleba, Foreman, Malleable Machine Molders, General Electric Co., Erie.
Harry H. Hatch, Foreman, Maintenance, General Electric Co., Erie, Pa.
George W. Heyer, Foreman, Core Room, General Electric Co., Erie, Pa.
S. V. Holmes, Core Room Foreman, Chicago Pneumatic Tool Co., Franklin, Pa.
Carl J. Martin, Foreman, Alloy Cleaning, General Electric Co., Erie, Pa.
William E. McLean, Foreman, Soft Iron Cleaning, General Electric Co., Erie, Pa.
Alfred H. Minhinnick, Electrician, General Electric Co., Erie, Pa.
Robert H. Shenk, Engr., Erie, Pa.
Gustave G. Weller, Time Study Leader, General Electric Co., Erie, Pa.
Roy D. Zimmerman, Inspection Head, General Electric Co., Erie, Pa.

ONTARIO CHAPTER

F. J. Francis, Metals & Alloys Ltd., Leaside, Ont., Canada.
Fred Lewis, Foundry Engr., Anthes Imperial Ltd., St. Catharines, Ont., Canada.

PHILADELPHIA CHAPTER

Che-Tyan Chang, Wilkening Mfg. Co., Philadelphia.

QUAD CITY CHAPTER

Edward R. Denz, Foundry Supt., Murray Iron Works, Burlington, Iowa.

ROCHESTER CHAPTER

John L. Collins, Foreman, The Anstice Co., Inc., Rochester, N. Y.
William B. Sattler, Sales Engr., Whitehead Bros. Co., New York City.

SAGINAW VALLEY CHAPTER

Harry R. Rose, Cooperative Engineering Student, Buick Motor Co., Flint, Mich.

ST. LOUIS DISTRICT CHAPTER

Jos. G. Fedora, Pattern Layout, General Steel Castings Corp., Granite City, Ill.

SOUTHERN CALIFORNIA CHAPTER

Robert M. Goin, Sales Mgr., Zirkite Refractory Products Co., Lynwood, Calif.
T. W. Harris, Sales, Wilson & Geo. Meyer & Co., Los Angeles.
E. C. Heyde, Foundry Supt., Apex Steel Corp., Los Angeles.
David L. Johns, Met. Engr., North American Aviation, Inc., Inglewood, Calif.
Griffith R. Jones, Clerk, Snyder Foundry Supply Co., Los Angeles.
Arthur B. Lamb, Service Engr., Independent Foundry Supply Co., Los Angeles.
William B. Logue, General Foreman, Kaiser Co., Fontana, Calif.
***Northrop Aircraft, Inc., Hawthorne, Calif. (T. E. Piper, Chief Process Engr.).**
R. N. Schaper, Westlectric Castings, Inc., Los Angeles.
C. E. Steele, Mgr., Ingersoll-Rand Co., Los Angeles.
A. H. Tatro, Owner, A. H. Tatro Supply Co., Los Angeles.
John J. Zets, Kaiser Co., Fontana, Calif.

TEXAS CHAPTER

Chas. W. Conner, Owner, Advance Brass Foundry, Houston.
W. J. Hambrick, Supt. of Melting, Hughes Tool Co., Houston.
J. M. Smith, Foreman, Hughes Tool Co., Houston.

TOLEDO CHAPTER

R. E. Bossert, Pattern Foreman, Maumee Malleable Castings Co., Toledo.
H. M. Breese, Purchasing Agent, Maumee Malleable Castings Co., Toledo.

TWIN CITY CHAPTER

Harry Hanson, Foundry Foreman, Smith System Foundry, Minneapolis.
Hans Stadem, Owner, Stadem Pattern Co., St. Paul.

WESTERN MICHIGAN CHAPTER

Jas. P. Jackson, Pyle Pattern & Mfg. Co., Muskegon Heights, Mich.
Ralph A. Johnson, Repr., Delta Oil Products Co., Grand Haven, Mich.

WESTERN NEW YORK CHAPTER

A. S. Coulter, Buffalo Repr., The Werner G. Smith Co., Div. Archer-Daniels-Midland Co., Buffalo, N. Y.
Four Continent Book Corp., New York City.
Thad. J. Toporczyk, Molder, Worthington Pump & Machinery Corp., Buffalo, N. Y.
Chas. F. Whitmore, Engr., Project or Design, Harrison Radiator Div., G.M.C., Lockport, N. Y.

WISCONSIN CHAPTER

N. Amrheim, Personnel Mgr., Federal Malleable Co., West Allis, Wis.
George V. Jedinak, Chief Inspector, Sivyer Steel Casting Co., Milwaukee.
Edwards Joers, Allis-Chalmers Mfg. Co., Milwaukee.
Charles T. Jorgensen, Dist. Mgr., Palmer Bee Co., Milwaukee.
J. R. Kosterman, Secy., M. J. Skubal Co., Milwaukee.
Ray Nelson, Owner, Nelson Pattern Co., Milwuakee.

*Company Member.

OUTSIDE OF CHAPTER

Sr. Jose Cardenas Aguirre, Supt., Cia. Industrial Del Norte, S. A., Saltillo, Coah., Mexico.
C. G. Dupriez, Engineer, Embourg, Belgium.
Basil A. H. Galloway, Sr. Met., Dept. of Aircraft Production, Melbourne, Australia.
***Hadfield Steel Works Ltd., Sydney, N.S.W., Australia (A. C. Waters).**
***Cia. Industrial Del Norte, S. A., Saltilio, Coah., Mexico.**
Office of War Information—Stockholm, c/o American Embassy, London, England.
H. J. Rowe, Chief Met., Castings Div., Aluminum Co. of America, Pittsburgh, Pa.
Ing. Juan Pablo Velasco, Mexico, D. F.
G. B. Wallwork, Dir., Henry Wallwork & Co. Ltd., Manchester, England.
K. J. Zwanziger, Technical Officer (Patternshop) Marine Etablissement Soerabaja, Johannesburg, South Africa.

Foundry Personalities

Clarence Carl Hermann, formerly general manager, Claude B. Schneible Co., Chicago, has left that concern to open his own office in Detroit as consulting mechanical *engineer, specializing on foundry* design and dust problems.

L. J. Wise

W. E. Brewster

L. B. Robertson, general superintendent at Wisconsin Steel Co., Chicago, since 1936, has retired. He has been replaced by **William E. Brewster,** assistant general superintendent since 1936. **Roy A. Lindgren,** formerly second assistant, has become assistant general superintendent. Both Messrs. Brewster and Lindgren are A.F.A. members and take part in Chicago chapter activities.

Dr. James Creese, vice-president, Stevens Institute of Technology, Hoboken, N. J., since 1928, has been named the sixth president of Drexel Institute of Technology, Philadelphia. Dr. Creese will assume his new duties October 1.

Dr. James Creese

Leon J. Wise, formerly assistant to executive vice-president, Allied Steel Castings Co., Chicago, has been named general manager. Mr. Wise is an A.F.A. member and a past chairman of the Chicago chapter. He also has been active on the A.F.A. Malleable Iron Division Advisory Committee.

A. S. Klopf, formerly with Firegan Sales Co., Chicago, has joined the staff of Lester B. Knight & Associates, Chicago, as a foundry engineer. Mr. Klopf is a Chicago chapter past president and is well known in foundry circles.

A. S. Klopf

M. F. Becker

M. F. Becker has resigned as vice-president, Whiting Corp., Harvey, Ill., after 25 continuous years with that company since graduating from Purdue University, Lafayette, Ind., in 1920. Long active in A.F.A. affairs, Mr. Becker is continuing in the foundry equipment business as a manufacturers' agent in the Chicago territory.

V. C. Bruce has recently joined the sales force of Frederic B. Stevens Inc., Detroit, and will make his headquarters The Hoosier Supply Co., Indianapolis. Mr. Bruce is the retiring chairman, Michiana chapter, and has taken an active part in its work since its inception.

V. C. Bruce

H. Picker

Harvey Picker, recently returned to inactive status by the Navy, has been elected president, Picker X-ray Corp., New York. **James Picker,** formerly president, is now chairman of the board.

Dr. Lauchlin M. Currie has been elected vice-president in charge of research, National Carbon Corp., it was announced recently. Dr. Currie has been acting director of research since 1942.

B. Vere Nutt, former executive vice-president, Moline Iron Works, Moline, Ill., has been elected chairman of the board.

Dr. L. M. Currie

B. Vere Nutt

(Concluded on Page 83)

1945-46 SEASON

Chapter Directory

Birmingham District Chapter

(Established 1936)

Chairman—J. A. Woody, American Cast Iron Pipe Co., Birmingham.
Vice-Chairman—T. H. Benners, Jr., T. H. Benners & Co., Birmingham.
Secretary-Treasurer—Fred K. Brown, Adams, Rowe & Norman, Inc., Birmingham.
Directors—W. Carson Adams, W. Carson Adams, Birmingham.
C. P. Caldwell, Caldwell Foundry & Machine Co., Birmingham.
R. R. Deas, Jr., American Cast Iron Pipe Co., Birmingham.
R. A. Donaldson, Kerchner, Marshall & Co., Birmingham.
J. T. Gilbert, Stockham Pipe Fittings Co., Birmingham.
Arthur Lee, Lee Bros. Foundry Co., Anniston, Ala.
J. T. MacKenzie, American Cast Iron Pipe Co., Birmingham.
Howard A. Nelson, Hill & Griffith Co., Birmingham.
E. A. Thomas, Thomas Foundries, Inc., Birmingham.
John F. Wakeland, McWane Cast Iron Pipe Co., Birmingham.

Canton District Chapter

(Established 1944)

Chairman—H. G. Robertson, American Steel Foundries, Alliance, Ohio.
Vice-Chairman—I. M. Emery, Massillon Steel Casting Co., Massillon, Ohio.
Vice-Chairman—C. F. Bunting, Pittsburgh Valve & Fittings Div., Pitcairn Co., Barberton, Ohio.
Secretary—C. E. Shaw, American Steel Foundries, Alliance, Ohio.
Treasurer—Otis D. Clay, Tuscora Foundry Sand Co., Canal Fulton, Ohio.
Directors—Earl Brown, Union Metal Mfg. Co., Canton, Ohio.
F. K. Donaldson, Machined Steel Castings Co., Alliance, Ohio.
Fred C. Glass, Deming Co., Salem, Ohio.
H. E. McKimmey, Carnegie-Illinois Steel Corp., Canton, Ohio.
Chas. W. McLaughlin, Barberton Foundry Co., Barberton, Ohio.
Chas. Reyman, Jr., Atlantic Foundry Co., Akron, Ohio.
Karl F. Schmidt, United Engineering & Foundry Co., Canton, Ohio.
Charles Scovill, Babcock & Wilcox Co., Barberton, Ohio.
Lewis Way, Columbiana Foundry Co., Columbiana, Ohio.
C. B. Williams, Massillon Steel Casting Co., Massillon, Ohio.

Central Indiana Chapter

(Established 1939)

Chairman—Ray S. Davis, National Malleable & Steel Castings Co., Indianapolis.
Vice-Chairman—J. P. Lentz, International Harvester Co., Indianapolis.
Treasurer—H. F. Henninger, International Harvester Co., Indianapolis.
Secretary—Robert Langsenkamp, Langsenkamp-Wheeler Brass Works, Inc., Indianapolis.
Directors—Richard H. Bancroft, Perfect Circle Co., New Castle, Ind.
Lloyd E. Davis, Republic Coal & Coke Co., Terre Haute, Ind.
G. C. Dickey, The Harrison Steel Castings Co., Attica, Ind.
Charles J. Gisler, C. & G. Foundry & Pattern Works, Indianapolis.
H. H. Lurie, Cummins Engine Co., Columbus, Ind.
B. P. Mulcahy, Citizens Gas & Coke Utility, Indianapolis.
Reid L. Palmer, Federal Foundry Co., Div. of American Stove Co., Indianapolis.
W. L. Seymour, Hoosier Iron Works, Kokomo, Ind.
L. C. Snyder, Hickman, Williams & Co., Cincinnati, Ohio.
W. F. Tragarz, International Harvester Co., Richmond, Ind.
William A. Zeunik, National Malleable & Steel Castings Co., Indianapolis.
William Zigmueller, Electric Steel Castings Co., Indianapolis.

Central New York Chapter

(Established 1939)

Chairman—E. G. White, Crouse-Hinds Co., Syracuse, N. Y.
Vice-Chairman—E. E. Hook, Dayton Oil Co., Syracuse, N. Y.
Secretary—R. A. Minnear, Ingersoll-Rand Co., Painted Post, N. Y.
Treasurer—M. G. Hollenbeck, Kennedy Valve Mfg. Co., Elmira, N. Y.
Directors—N. Paul Benson, Frazer & Jones Co. Inc., Syracuse, N. Y.
N. H. Boardman, Elmira Foundry Co., Elmira, N. Y.
David Dudgeon, Jr., Utica Radiator Corp., Utica, N. Y.
H. S. Gulick, New York Air Brake Co., Watertown, N. Y.
L. E. Hall, Syracuse Chilled Plow Co. Inc., Syracuse, N. Y.
Arthur C. Hintz, Rensselaer Valve Co. Inc., Troy, N. Y.
J. F. Livingston, Crouse-Hinds Co., Syracuse, N. Y.
I. F. Vergamini, Goulds Pumps, Inc., Seneca Falls, N. Y.
L. D. Wright, U. S. Radiator Corp., Geneva, N. Y.

Central Ohio Chapter

(Established 1945)

Chairman—Tom E. Barlow, Battelle Memorial Institute, Columbus, Ohio.
Co-Chairman—Norman J. Dunbeck, Eastern Clay Products Co., Eifort, Ohio.
Secretary—Karol W. Whitlatch, Aetna Fire Brick Co., Oak Hill, Ohio.
Treasurer—R. H. Frank, Bonney-Floyd Co., Columbus, Ohio.
Directors—Fred W. Fuller, National Engineering Co., Columbus, Ohio.
William R. Huffman, H. B. Salter Mfg. Co., Marysville, Ohio.
Frank Kiper, Ohio Steel Foundry Co., Springfield, Ohio.
John F. Lacey, Commercial Steel Casting Co., Marion, Ohio.
H. Kenneth McGrath, Alten's Foundry & Machine Works, Lancaster, Ohio.
Karl G. Presser, National Supply Co., Springfield, Ohio.
David M. Whyte, Cooper-Bessemer Corp., Mt. Vernon, Ohio.
J. J. Witenhafer, Columbus Malleable Iron Co., Columbus, Ohio.

Chesapeake Chapter

(Established 1940)

Chairman—Howard F. Taylor, Naval Research Laboratory, Anacostia Sta., Washington, D. C.
Vice-Chairman—David Tamor, American Chain & Cable Co. Inc., American Chain Div., York, Pa.
Honorary Chairman—E. W. Horlebein, Gibson & Kirk Co., Baltimore, Md.
Secretary-Treasurer—L. H. Denton, Baltimore Convention Bureau, Baltimore, Md.
Technical Secretary—Dr. Blake M. Loring, Naval Research Laboratory, Bellevue, Washington, D. C.
Directors—R. T. Covington, American Hammered Piston Ring Div., Koppers Co., Baltimore, Md.
J. E. Crown, U. S. Navy Yard, Washington, D. C.
William H. Holtz, American Brake Shoe Co., Baltimore, Md.

H. A. Horner, Frick Co., Inc., Waynesboro, Pa.
Wallace W. Levi, Lynchburg Foundry Co., Lynchburg, Va.
J. B. Mentzer, Wood-Embly Brass Co., Waynesboro, Pa.
J. W. Mentzer, Taggart & Co., Philadelphia, Pa.
H. F. Poper, Frick Co., Inc., Waynesboro, Pa.
G. L. Webster, Baltimore Polytechnic Institute, Baltimore, Md.

Chicago Chapter

(Established 1934)

Chairman—J. C. Gore, Werner G. Smith Co., Div. Archer-Daniels-Midland Co., Chicago.
Vice-Chairman—F. E. Wartgow, Hasbrouck Haynes, Engineers, Chicago.
Secretary—L. C. Smith, Peninsular Grinding Wheel Co., Chicago.
Treasurer—B. L. Simpson, National Engineering Co., Chicago.
Directors—M. F. Becker, 8103 So. Langley Ave., Chicago.
C. K. Faunt, Christensen & Olson Foundry Co., Chicago.
A. G. Gierach, American Manganese Steel Div., American Brake Shoe Co., Chicago Heights, Ill.
L. H. Hahn, Sivyer Steel Casting Co., Chicago.
A. S. Klopf, Lester B. Knight & Associates, Chicago.
D. H. Lucas, 1511 Touhy Ave., Chicago.
C. G. Mate, Greenlee Foundry Co., Chicago.
W. D. McMillan, International Harvester Co., Chicago.
H. M. St. John, Crane Co., Chicago.
A. K. Sanderson, Love Bros., Inc., Aurora, Ill.
H. K. Swanson, Swanson Pattern & Model Works, East Chicago, Ind.
Dr. R. F. Thomson, Dodge Chicago Plant, Chrysler Corp., Chicago.

Cincinnati Chapter

(Established 1939)

Chairman—A. W. Schneble, Sr., The Advance Foundry Co., Dayton, Ohio.
Vice-Chairman—Jos. S. Schumacher, Hill & Griffith Co., Cincinnati.
Secretary—Wm. H. Hoppenjans, Jr., Star Foundry Co., Covington, Ky.
Treasurer—Wm. J. Love, Jr., Lunkenheimer Co., Cincinnati.
Directors—Emil Albrecht, Aluminum Foundry Co., Cincinnati.
Arthur Alfers, Oakley Pattern & Foundry Co., Cincinnati.
W. J. Buvinger, Buckeye Foundry Co., Cincinnati.
Charles E. Dine, St. Marys Foundry Co., St. Marys, Ohio.
R. G. Ebersole, Miller & Co., Cincinnati.
Luke D. Fahey, Dayton Castings Co., Dayton, Ohio.
Edgar Kihn, Cincinnati Milling Machine Co., Cincinnati.
Charles E. Koehler, Hamilton Brass & Aluminum Castings Co., Hamilton, Ohio.
Stanley F. Levy, Black-Clawson Co., Hamilton, Ohio.
H. F. McVay, Delhi Foundry Sand Co., Cincinnati.
Charles D. Steinmeier, A. D. Cook, Inc., Lawrenceburg, Ind.
George S. Twachtman, Chris Erhart Foundry & Machine Co., Cincinnati.

Detroit Chapter

(Established 1935)

Chairman—E. C. Hoenicke, Eaton-Erb Foundry Div., Eaton Mfg. Co., Detroit.
Vice-Chairman—A. H. Allen, Penton Publishing Co., Detroit.
Treasurer—W. W. Bowring, Frederic B. Stevens, Inc., Detroit.
Secretary—H. H. Wilder, Wilson Foundry & Machine Co., Pontiac, Mich.
Directors—Omer L. Allen, Pontiac Motor Div., General Motors Corp., Pontiac, Mich.
O. F. Carpenter, Packard Motor Car Co., Detroit.
J. P. Carritte, Jr., True Alloys Inc., Detroit.
Gordon C. Creusere, Semet-Solvay Co., Detroit.
E. R. Darby, Federal Mogul Corp., Detroit.
G. A. Fuller, Federal Foundry Supply Co., Detroit.
G. L. Galmish, Michigan Malleable Iron Co., Detroit.
John E. Linabury, General Motors Corp., Detroit.
R. G. McElwee, Vanadium Corp. of America, Detroit.
C. E. Silver, Michigan Steel Castings Co., Detroit.
A. W. Stolzenburg, Aluminum Co. of America, Detroit.
G. Vennerholm, Ford Motor Co., Detroit.

Eastern Canada and Newfoundland Chapter

(Established 1942)

Chairman—G. Ewing Tait, Dominion Engineering Works, Lachine, Que.
Vice-Chairman—Henri Louette, Warden King Ltd., Montreal, Que.
Secretary-Treasurer—Robert E. Cameron, Webster & Sons Ltd., Montreal, Que.
Directors—Del. Allard, Arts & Crafts School, Provincial Government, Montreal, Que.
W. Baxter, Crane Ltd., Montreal, Que.
A. E. Cartwright, Robert Mitchell Co. Ltd., St. Laurent, Que.
C. V. Hacker, Hull Iron & Steel Foundries Ltd., Hull, Que.
Ed. Laurendeau, Canadian Pattern & Woodworking Co., Montreal, Que.
R. Leclair, Dominion Engineering Works Ltd., Lachine, Que.
A. C. Neal, Enamel & Heating Products Ltd., Amherst, N. S.
James H. Newman, Chamberlain Engineering (Canada) Ltd., Montreal, Que.
Alex Pirrie, Electric Steels Ltd., Cap de-la-Madeleine, Que.
O. H. Seveigny, Lynn MacLeod Metallurgy Ltd., Thetford Mines, Que.
G. D. Turnbull, Canadian Car & Foundry Co. Ltd., Montreal, Que.
A. R. Woods, Canadian Foundry Supplies & Equipment Co. Ltd., Montreal, Que.

Metropolitan Chapter

(Established 1938)

Chairman—Horace A. Deane, American Brake Shoe Co., New York.
Vice-Chairman—Harold L. Ullrich, Sacks Barlow Foundries Inc., Newark, N. J.
Secretary—George E. Hadzima, Robins Conveyors Inc., Passaic, N. J.
Treasurer—H. B. Caldwell, Whiting Corp., New York.
Directors—H. F. Biddle, Foran Foundry & Mfg. Co., Flemington, N. J.
C. H. Cline, Malcolm Foundry Co., Inc., Newark, N. J.
H. C. Harris, Mack Mfg. Co., New Brunswick, N. J.
Clifford J. Law, Worthington Pump & Machinery Corp., Harrison, N. J.
A. B. McCullough, American Steel Castings Co., Newark, N. J.
Alex McIntosh, Wright Aeronautical Corp., Paterson, N. J.
William E. Paulson, Thos. Paulson & Son, Inc., Brooklyn, N. Y.
J. S. Vanick, International Nickel Co., New York.
R. E. Ward, Eclipse-Pioneer Div., Bendix Aviation Corp., Teterboro, N. J.
D. S. Yeomans, George F. Pettinos, East Orange, N. J.

Michiana Chapter

(Established 1940)

Chairman—W. V. Johnson, Oliver Farm Equipment Co., South Bend, Ind.
Vice-Chairman—John J. McAntee, Covel Mfg. Co., Benton Harbor, Mich.
Secretary-Treasurer—V. S. Spears, American Foundry Equipment Co., Mishawaka, Ind.
Directors—H. E. Ardahl, Michiana Products Co., Michigan City, Ind.
Earl Byers, Sibley Machine & Foundry Co., South Bend, Ind.
J. E. Digan, Logansport Foundry Industries Inc., Logansport, Ind.
C. O. Hiler, Bantam Bearings Div., Torrington Co., South Bend, Ind.
M. J. Lefler, Strom Brass Foundry, Elkhart, Ind.
John MacDonald, Round Oak Furnace Co., Dowagiac, Mich.
J. C. Manning, Clark Equipment Co., Buchanan, Mich.
G. O. McCray, Bendix Products Div., South Bend, Ind.
J. H. Miller, Josam Products Foundry Co., Michigan City, Ind.
K. A. Nelson, Chicago Hardware Foundry Co., Elkhart, Ind.
M. F. Surls, Clark Equipment Co., Buchanan, Mich.
H. B. Voorhees, Dodge Mfg. Co., Mishawaka, Ind.

Northeastern Ohio Chapter

(Established 1935)

President—A. C. Denison, Fulton Foundry & Machine Co., Inc., Cleveland.
Vice-President—Henry J. Trenkamp, Ohio Foundry Co., Cleveland.
Secretary—Gilbert J. Nock, Nock Fire Brick Co., Cleveland.
Treasurer—F. Ray Fleig, Smith Facing & Supply Co., Cleveland.
Directors—Bruce Aiken, Crucible Steel Casting Co., Cleveland.
Frank C. Cech, Cleveland Trade School, Cleveland.
David Clark, Forest City Foundries Co., Cleveland.
Joseph E. Dvorak, Eberhard Mfg. Div., Eastern Malleable Iron Co., Cleveland.
H. C. Gollmar, Elyria Foundry Div., Industrial Brownhoist Corp., Elyria, Ohio.
J. B. Heisler, A. C. Williams Co., Ravenna, Ohio.
Russell F. Lincoln, R. F. Lincoln & Co., Lakewood, Ohio.
Edward J. Metzger, Wellman Bronze & Aluminum Co., Cleveland.
Leon F. Miller, Osborn Mfg. Co., Cleveland.
Bertram S. Parker, Jr., Youngstown Foundry & Machine Co., Youngstown, Ohio.
H. F. Roberts, Williams & Co., Cleveland.
Frank Weisehan, Ferro Machine & Foundry Co., Cleveland.
Thomas D. West, West Steel Casting Co., Cleveland.
Paul Wheeler, Link-Belt Co., Cleveland.
Elmer Zirzow, National Malleable & Steel Casting Co., Cleveland.

Northern California Chapter

(Established 1935)

President—Charles Hoehn, Jr., Enterprise Engine & Foundry Co., San Francisco.
Vice-President—Richard Vosbrink, Berkeley Pattern Works, Berkeley, Calif.
Secretary-Treasurer—Geo. L. Kennard, Northern California Foundrymen's Institute, San Francisco.
Directors—H. A. Bossi, H. C. Macaulay Foundry Co., Berkeley, Calif.
J. B. Bubb, Joshua Hendy Iron Works, Sunnyvale, Calif.
Herbert E. Eggerts, Berkeley Brass Foundry Co., Berkeley, Calif.
Harold E. Henderson, H. C. Macaulay Foundry Co., Berkeley, Calif.
Wm. G. Leishman, Pacific Brass Foundry of San Francisco, San Francisco, Calif.
A. M. Ondreyco., Vulcan Foundry Co., Oakland, Calif.
G. W. Penning, Enterprise Engine & Foundry Co., Richmond, Calif.
R. C. Noah, San Francisco Iron Foundry, Inc., San Francisco, Calif.

Northern Illinois and Southern Wisconsin Chapter

(Established 1938)

Chairman—John Roy Cochran, Sundstrand Machine Tool Co., Rockford, Ill.
Vice-Chairman—A. Gunnard Anderson, W. L. Davey Pump Corp., Rockford, Ill.
Secretary—A. P. Rose, National Sewing Machine Co., Belvidere, Ill.
Treasurer—John Doerfner, Jr., Gunite Foundries Corp., Rockford, Ill.
Directors—H. J. Bauman, Ebaloy Foundries Inc., Rockford, Ill.
Roy D. Baysinger, Geo. D. Roper Corp., Rockford, Ill.
William Bucholtz, Beloit Foundry Co., Beloit, Wis.
Lyle Fulton, Geo. D. Roper Corp., Rockford, Ill.
John N. Johnson, J. I. Case Co., Rockford, Ill.
R. J. Looze, Beloit Iron Works, Beloit, Wis.
R. W. Mattison, Mattison Machine Works, Rockford, Ill.
Max J. Reuteler, Fairbanks, Morse & Co., Beloit, Wis.
F. N. Rundquist, Beloit Castings Co., Beloit, Wis.

Northwestern Pennsylvania Chapter

(Established 1945)

Chairman—Roger W. Griswold, Jr., Griswold Mfg. Co., Erie.
Vice-Chairman—Earl M. Strick, Erie Malleable Iron Co., Erie.
Secretary—H. L. Gebhardt, United Oil Mfg. Co., Erie.
Treasurer—Ray W. Britton, Urick Foundry, Erie.
Directors—T. H. Beaulac, Chicago Pneumatic Tool Co., Franklin, Pa.
Roger D. Carver, Standard Stoker Co., Erie.
Lawrence A. Dunn, General Electric Co., Erie.
Clarence Fitz, Hays Mfg. Co., Erie.
Kenneth T. Guyer, Bucyrus-Erie Co., Erie.
J. S. Hornstein, Meadville Malleable Iron Co., Meadville, Pa.
Douglas J. James, Erie City Iron Works, Erie.
William J. Miller, Frederic B. Stevens, Inc., Erie.
J. L. Skinner, Skinner Engine Co., Erie.
Ralph T. Wedgwood, Pickands Mather & Co., Erie.

Ontario Chapter

(Established 1938)

Chairman—T. D. Barnes, Don Barnes Foundry Supplies & Equipment, Hamilton, Ont.
Vice-Chairman—J. A. Wotherspoon, Anthes-Imperial Ltd., St. Catharines, Ont.
Secretary-Treasurer—G. L. White, Westman Publications Ltd., Toronto, Ont.
Directors—W. J. Brill, Canadian General Electric Co. Ltd., Toronto, Ont.
H. E. Craddock, Beatty Bros. Ltd., London, Ont.
James Dalby, Canada Metal Co. Ltd., Toronto, Ont.
D. H. Gilbert, Dominion Wheel & Foundries Ltd., St. Boniface, Manitoba.
J. H. King, Werner G. Smith Ltd., Toronto, Ont.
L. B. Morris, The Gurney Foundry Co. Ltd., Toronto, Ont.
R. T. Robertson, International Harvester Co. of Canada Ltd., Hamilton, Ont.
E. G. Storie, Fittings Ltd., Oshawa, Ont.
Theo. Tafel, Standard Sanitary & Dominion Radiator Ltd., Toronto, Ont.
M. N. Tallman, A. H. Tallman Bronze Co. Ltd., Hamilton, Ont.
R. A. Woods, Geo. F. Pettinos (Canada) Ltd., Hamilton, Ont.

Oregon Chapter

(Established 1945)

Chairman—W. R. Pindell, Northwest Stove & Furnace Works, Inc., Portland.
Vice-Chairman—Nate Weinger, Peninsula Foundry Co., Portland.
Secretary-Treasurer—A. R. Prier, Oregon Brass Works Inc., Portland.
Directors—A. J. Grbavac, Columbia Steel Casting Co., Portland.
A. B. Holmes, Crawford & Doherty Foundry Co., Portland.
Frank A. Miller, Western Industrial Supply Co., Portland.
S. E. Peeler, Electric Steel Foundry, Portland.
W. R. Pindell, Northwest Stove & Furnace Works, Inc., Portland.
A. R. Prier, Oregon Brass Works Inc., Portland.
F. A. Stephenson, Dependable Pattern Works, Portland.
H. L. Tatham, Pacific Steel Foundry, Portland.
Nate Weinger, Peninsula Foundry Co., Portland.

Philadelphia Chapter

(Established 1935)

Chairman—John M. Robb, Jr., Hickman Williams & Co., Philadelphia.
Vice-Chairman—B. A. Miller, Cramp Brass & Iron Foundries Div., Baldwin Locomotive Works, Philadelphia.
Secretary-Treasurer—W. B. Coleman, W. B. Coleman & Co., Philadelphia.
Directors—Earl Eastburn, Phosphor Bronze Smelting Co., Philadelphia.
C. L. Lane, Florence Pipe Foundry & Machine Co., Florence, N. J.
Robert Latham, Bethlehem Steel Co., Bethlehem, Pa.
H. E. Mandel, Pennsylvania Foundry Supply & Sand Co., Philadelphia.
J. W. March, Camden Foundry Co., Camden, N. J.
E. C. Troy, Dodge Steel Co., Philadelphia.
H. V. Witherington, H. W. Butterworth & Sons Co., Bethayres, Pa.

Quad City Chapter

(Established 1935)

Chairman—C. E. Von Luhrte, Chicago Retort & Fire Brick Co., Davenport, Iowa.
Vice-Chairman—C. S. Humphrey, C. S. Humphrey Co., Moline, Ill.
Secretary-Treasurer—W. H. Sundeen, Ordnance Steel Foundry Co., Bettendorf, Iowa.
Directors—H. L. Creps, Frank Foundries Corp., Moline, Ill.
W. E. Jones, Ordnance Steel Foundry Co., Bettendorf, Iowa.
M. H. Liedtke, International Harvester Co., Rock Island, Ill.
A. D. Matheson, French & Hecht, Inc., Davenport, Iowa.
A. H. Putnam, A. H. Putnam Co., Rock Island, Ill.
F. W. Shipley, Caterpillar Tractor Co., Peoria, Ill.
R. H. Swartz, Ordnance Steel Foundry Co., Bettendorf, Iowa.
A. Van Lantschoot, Iowa Malleable Iron Co., Fairfield, Iowa.
R. E. Wilke, Deere & Co., Moline, Ill.

Rochester Chapter

(Established 1944)

President—Walter F. Morton, The Anstice Co., Inc., Rochester.
Vice-President—Walter G. Brayer, Bausch & Lomb Optical Co., Rochester.
Secretary-Treasurer—Carl B. Johnson, Symington-Gould Corp., Rochester.
Directors—David D. Baxter, Sterling Wheelbarrow Co., Rochester.
I. A. Billiar, Symington-Gould Corp., Rochester.
Walter G. Brayer, Bausch & Lomb Optical Co., Rochester.
Neal F. Clement, Rochester-Erie Foundry Corp., Rochester.
M. T. Ganzauge, General Railway Signal Co., Rochester.
L. C. Gleason, Gleason Works, Rochester.
Henry B. Hanley, American Laundry Machinery Co., Rochester.
Herman G. Hetzler, Hetzler Foundries, Inc., Rochester.
Irving B. Rosenthal, Rochester Smelting & Refining Co., Rochester.
*Ernest N. VanBilliard, Progressive Foundry Works Inc., Rochester.

**Deceased.*

Saginaw Valley Chapter

(Established 1945)

Chairman—H. G. McMurry, Buick Motor Div., General Motors Corp., Flint, Mich.
Vice-Chairman—John F. Smith, Chevrolet Grey Iron Foundry, Saginaw, Mich.
Secretary-Treasurer—M. V. Chamberlin, Dow Chemical Co., Midland, Mich.
Directors—E. H. Bankard, Buick Motor Div., General Motors Corp., Flint, Mich.
J. E. Bowen, Chevrolet Grey Iron Foundry, Saginaw, Mich.
F. S. Brewster, Dow Chemical Co., Bay City, Mich.
R. H. Mooney, Saginaw Malleable Iron Div., General Motors Corp., Saginaw, Mich.
Charles Morrison, Saginaw Malleable Iron Div., General Motors Corp., Saginaw, Mich.
K. H. Priestley, Eaton-Erb Foundry Div., Eaton Mfg. Co., Vassar, Mich.
A. E. Rhoads, Detroit Electric Furnace Div., Kuhlman Electric Co., Bay City, Mich.
O. E. Sundstedt, General Foundries & Mfg. Co., Flint, Mich.
C. A. Tobias, General Motors Institute of Technology, Flint, Mich.
Earl Wise, Baker-Perkins Inc., Saginaw, Mich.

St. Louis District Chapter

(Established 1935)

Chairman—Walter E. Illig, Banner Iron Works, St. Louis.
Vice-Chairman—Roland T. Leisk, American Steel Foundries, East St. Louis, Ill.
Secretary-Treasurer—Lee H. Horneyer, 7 N. Grand Blvd., St. Louis.
Directors—E. Eugene Ballard, National Bearing Div., American Brake Shoe Co., St. Louis.
J. R. Bodine, Bodine Pattern & Foundry Co., St. Louis.
Ralph M. Hill, Jr., East St. Louis Castings Co., East St. Louis, Ill.
Roy A. Jacobsen, Carondelet Foundry Co., St. Louis.
John W. Kelin, Federated Metals Div., American Smelting & Refining Co., St. Louis.
L. A. Kleber, General Steel Castings Corp., Granite City, Ill.
Fred B. Riggan, Key Co., East St. Louis, Ill.
Chester H. J. Walcher, American Steel Foundries, Granite City, Ill.
Joseph D. Walsh, Scullin Steel Co., St. Louis.
Herman Weible, Maco Foundry & Enamel Shop, St. Louis.
Harold Wiese, 731 N. Kingshighway Blvd., St. Louis.
J. H. Williamson, M. A. Bell Co., St. Louis.

Southern California Chapter

(Established 1937)

President—Robert R. Haley, Advance Aluminum & Brass Co., Los Angeles.
Vice-President—Wm. D. Emmett, Los Angeles Steel Castings Co., Los Angeles.
Secretary—Henry E. Russill, Eld Metal Co., Ltd., Los Angeles.
Treasurer—L. O. Hofstetter, Brumley-Donaldson & Co., Los Angeles.
Directors—Roy F. Barner, Snyder Foundry Supply Co., Los Angeles.
Victor P. Barton, Triplett & Barton, Inc., Burbank, Calif.
J. F. Cassel, Compton Metals Co., Compton, Calif.
L. N. Coleman, Rich Mfg. Co., Los Angeles.
J. M. Crawford, Snyder Engineering Corp., Los Angeles.
Chas. R. Gregg, Reliance Regulator Co., Alhambra, Calif.
Henry W. Howell, Howell Foundry, Los Nietos, Calif.
H. G. Pagenkopp, Angelus Pattern Works, Huntington Park, Calif.

Texas Chapter

(Established 1943)

Chairman—E. P. Trout, Lufkin Foundry & Machine Co., Lufkin, Texas.
Vice-Chairman—William Murray Ferguson, Texas Electric Steel Casting Co., Houston.
Secretary-Treasurer—H. L. Wren, R. Lavin & Sons, Inc., Houston.
Directors—J. Dee, Dee Brass Foundry, Houston.
W. C. Fleming, Hughes Tool Co., Houston.
Phillip Hawkins, Texas Steel Co., Fort Worth, Texas.
W. E. Hockmuth, Houston Foundry & Machine Co., Houston.
J. O. Klein, Texas Foundries, Inc., Lufkin, Texas.
Robert Lang, Lufkin Foundry & Machine Co., Lufkin, Texas.
B. Owen Murphy, Star Foundry Co., Houston.
T. W. Russell, Service Pattern & Model Works, Houston.
Arthur H. Stenzel, Stenzel Pattern Works, Houston.
W. J. Temple, Kincaid-Osborn Electric Steel Co., Inc., San Antonio, Texas.

Toledo Chapter

(Established 1941)

Chairman—N. P. Mahoney, Maumee Malleable Castings Co., Toledo.
Vice-Chairman—B. L. Pickett, Unitcast Corp., Toledo.
Secretary-Treasurer—Gerald R. Rusk, Freeman Supply Co., Toledo.
Directors—R. B. Bunting, Bunting Brass & Bronze Co., Toledo.
Chas. F. Carson, National Supply Co., Toledo.
Floyd F. Ensign, The Ensign Foundry Co., Toledo.
R. T. Jansen, Unitcast Corp., Toledo.
Leighton M. Long, Leighton M. Long & Associates, Toledo.
W. P. Mack, Bruce Foundry Co., Tecumseh, Mich.
N. P. Mahoney, Maumee Malleable Castings Co., Toledo.
Gerald R. Rusk, Freeman Supply Co., Toledo.
V. E. Zang, Unitcast Corp., Toledo.

Twin City Chapter

(Established 1941)

Chairman—R. C. Wood, Minneapolis Electric Steel Castings Co., Minneapolis.
Vice-Chairman—H. M. Patton, American Hoist & Derrick Co., St. Paul.
Secretary-Treasurer—Alexis Caswell, Manufacturers' Association of Minneapolis, Inc., Minneapolis.
Directors—Clifford Anderson, Crown Iron Works Co., Minneapolis.
H. J. Bierman, Acme Foundry Co., Minneapolis.
Axel F. Carlstrom, Smith-Sharpe Co., Minneapolis.
I. F. Cheney, Griffin Wheel Co., St. Paul.
A. M. Fulton, Northern Malleable Iron Co., St. Paul.
J. S. Garske, Progress Pattern & Foundry Co., St. Paul.
Fulton Holtby, University of Minnesota, Minneapolis.
Herbert Larson, Minneapolis-Moline Power Implement Co., Minneapolis.
Sheldon P. Pufahl, Paul Pufahl & Son Foundry Co., Minneapolis.

Western Michigan Chapter

(Established 1941)

Chairman—J. Wesley Lee, Challenge Machinery Co., Grand Haven, Mich.
Vice-Chairman—Fred C. McCarthy, Wolverine Brass Works, Grand Rapids, Mich.
Secretary—Rudolph Flora, Clover Foundry Co., Muskegon, Mich.
Treasurer—Arthur Green, Dake Engine Co., Grand Haven, Mich.
Directors—Joseph L. Brooks, Muskegon Piston Ring Co., Sparta, Mich.
R. R. Campbell, Centrifugal Casting Co., Muskegon, Mich.
Charles H. Cousineau, West Michigan Steel Foundry Co., Muskegon, Mich.
R. W. Hathaway, Federal Mogul Co., Greenville, Mich.
J. C. Jensen, Battle Creek Foundry Co., Battle Creek, Mich.
H. J. Krause, Newaygo Engineering Co., Newaygo, Mich.
W. R. Krepps, Campbell, Wyant & Cannon Foundry Co., Muskegon, Mich.
J. Wesley Lee, Challenge Machinery Co., Grand Haven, Mich.
George W. Myers, West Michigan Steel Foundry Co., Muskegon, Mich.
Harold N. Myers, Sealed Power Corp., Muskegon, Mich.
A. G. Radditz, Lakeshore Machinery & Supply Co., Muskegon, Mich.

Western New York Chapter

(Established 1937)

Chairman—Arthur H. Suckow, Symington-Gould Corp., Depew, N. Y.
Vice-Chairman—Henry C. Winte, Worthington Pump & Machinery Corp., Buffalo.
Secretary—Leo A. Merryman, Tonawanda Iron Corp., No. Tonawanda, N. Y.
Treasurer—Martin W. Pohlman, Pohlman Foundry Co., Inc., Buffalo.
Directors—Charles O. Burgess, Union Carbide & Carbon Research Laboratories, Niagara Falls, N. Y.
Alfred A. Diebold, Atlas Steel Casting Co., Buffalo.
Wilton S. Finley, 81 Linden Ave., Buffalo.
John C. Goetz, Acme Steel & Malleable Iron Works, Buffalo.
Avitus J. Heysel, E. J. Woodison Co., Buffalo.
Harold R. King, McCallum-Hatch Bronze Co., Inc., Buffalo.
Reinhold D. Loesch, Lake Erie Foundry Co., Buffalo.
Frank T. McQuillin, Standard Buffalo Foundry, Inc., Buffalo.
Martin J. O'Brien, Symington-Gould Corp., Depew, N. Y.
Harold J. Struebing, Electro Refractories & Alloys Corp., Buffalo.

Wisconsin Chapter

(Established 1935)

President—John Bing, A. P. Green Fire Brick Co., Milwaukee.
Vice-President—David C. Zuege, Sivyer Steel Casting Co., Milwaukee.
Secretary—R. J. Anderson, Belle City Malleable Iron Co., Racine, Wis.
Treasurer—R. F. Jordan, Sterling Wheelbarrow Co., Milwaukee.
Directors—M. A. Dantzler, Rundle Mfg. Co., Milwaukee.
William Eck, Wisconsin Aluminum Foundry Co., Manitowoc, Wis.
J. J. Ewens, Smith Steel & Milwaukee Steel Foundry Divs., Grede Foundries, Inc., Milwaukee.
A. M. Fischer, Chas. Jurack Co., Milwaukee.
Arthur C. Haack, Wisconsin Grey Iron Foundry Co., Milwaukee.
H. E. Ladwig, Allis-Chalmers Mfg. Co., Milwaukee.
Paul Rice, Milwaukee Chaplet & Mfg. Co., Milwaukee.
Robert C. Woodward, Bucyrus-Erie Co., So. Milwaukee.

Foundry Personalities

(Continued from Page 78)

Harold G. Evans, plant superintendent, Allied Steel Castings Co., Chicago, has been appointed works manager. **William Harrison,** foundry superintendent, succeeds Mr. Evans as plant superintendent.

Maurice C. Taylor, formerly manager of research, Niagara Falls Laboratories, The Mathieson Alkali Works, has been appointed resident director of research and development. Other research department changes are announced as follows: **J. Douglas MacMahon,** heretofore assistant manager, sales development department, has been named assistant to the technical director; **C. N. Richardson,** superintendent of pilot operations, becomes manager of research engineering; and **C. Gerald Day,** a superintendent in the development department, becomes research and plant liaison engineer.

E. A. Hund, associated with the foundry equipment industry since 1926, has been added to the staff of Lester B. Knight & Associates, Chicago, as senior engineer.

R. L. Hartford, Pittsburgh district editor of *Steel,* has been appointed assistant manager of research and promotion for *Steel* with headquarters in Cleveland. Mr. Hartford is succeeded as Pittsburgh editor by **J. C. Sullivan.**

Ward F. Martin, former president, G & N Mfg. Co., Cleveland, and recently in charge of die casting machine sales, Cleveland Automatic Machine Co., Cleveland, has founded a new firm, Light Metal Machinery, Inc., Erie, Pa.

Obituary

Neil I. McArthur, vice-president, Great Lakes Foundry Sand Co., Detroit, died July 24.

Whiting Corp. Aids in Producing Atomic Bomb

ONE of the industries that contributed to the research and production of the atomic bomb was Whiting Corp., Harvey, Ill. Whiting's principal contribution consisted of special equipment essential to the manufacture of the bomb which helped bring about world peace.

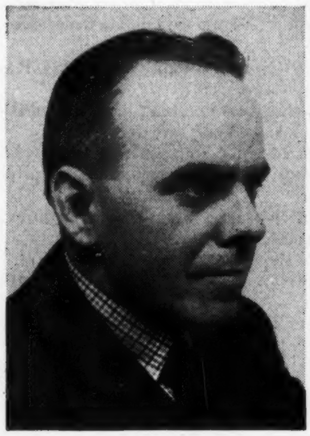
CHAPTER OFFICERS

H. G. Robertson
American Steel Foundries,
Alliance, Ohio
Chairman
Canton District Chapter

J. R. Cochran
Sundstrand Machine Tool Co.,
Rockford, Ill.
Chairman
No. Ill. and So. Wis. Chapter

H. G. McMurry
Buick Motor Div., General Motors
Corp., Flint, Mich.
Chairman
Saginaw Valley Chapter

A. H. Suckow
Symington-Gould Corp.,
Depew, N. Y.
Chairman
Western New York Chapter



John Bing
A. P. Green Fire Brick Co.,
Milwaukee, Wis.
Chairman
Wisconsin Chapter

A. C. Denison
Fulton Foundry & Machine Co.,
Cleveland, Ohio
Chairman
Northeastern Ohio Chapter

J. A. Woody
American Cast Iron Pipe Co.,
Birmingham, Ala.
Chairman
Birmingham District Chapter

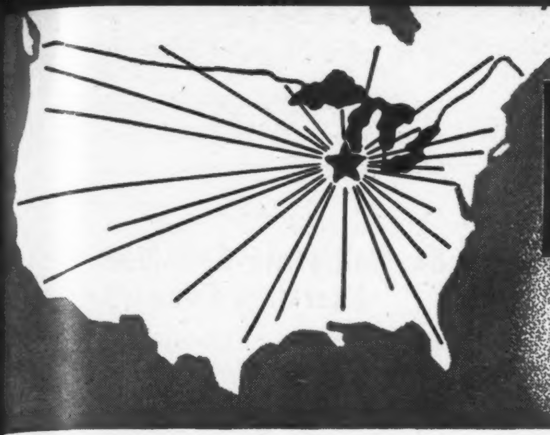
E. P. Trout
Lufkin Foundry & Machine Co.,
Lufkin, Texas
Chairman
Texas Chapter

R. C. Wood
Minneapolis Electric Steel
Castings Co.,
Minneapolis, Minn.
Chairman
Twin City Chapter

W. F. Morton
The Anstice Co.,
Rochester, N. Y.
Chairman
Rochester Chapter

Charles Hoehn, Jr.
Enterprise Engine & Foundry Co.,
San Francisco, Calif.
Chairman
Northern California Chapter

F. E. Wartgow
Hasbrouck Haynes, Engineers
Chicago, Ill.
Vice-Chairman
Chicago Chapter



CHAPTER ACTIVITIES *News*

WISCONSIN OUTING

Throng Not Fair Weather Friends

ON July 20, the Wisconsin Chapter held its annual golf outing at the Ozaukee Country Club. A very enthusiastic group of 700 men played golf, cards, and indulged in other sports despite the fact that the day was cloudy and at various times a slight drizzle made its appearance.

A fine buffet dinner was served in the evening and immediately afterward the prizes were awarded. A well planned floor show climaxed a very fine enjoyable day.

The pictures at the bottom of the page illustrate quite easily that the Badger state foundrymen have a good time at their outings. Each year this chapter's outing grows larger and larger.

News Bulletin to Members Twin City Chapter Issues

A NEWS BULLETIN called *"The Shakeout"* is now being published by the Twin City chapter and distributed monthly to its membership. It contains numerous interesting items of local interest and keeps the chapter foundrymen up-to-date on events happening in their vicinity. The editors have done a fine job in putting out their first edition and should be congratulated.

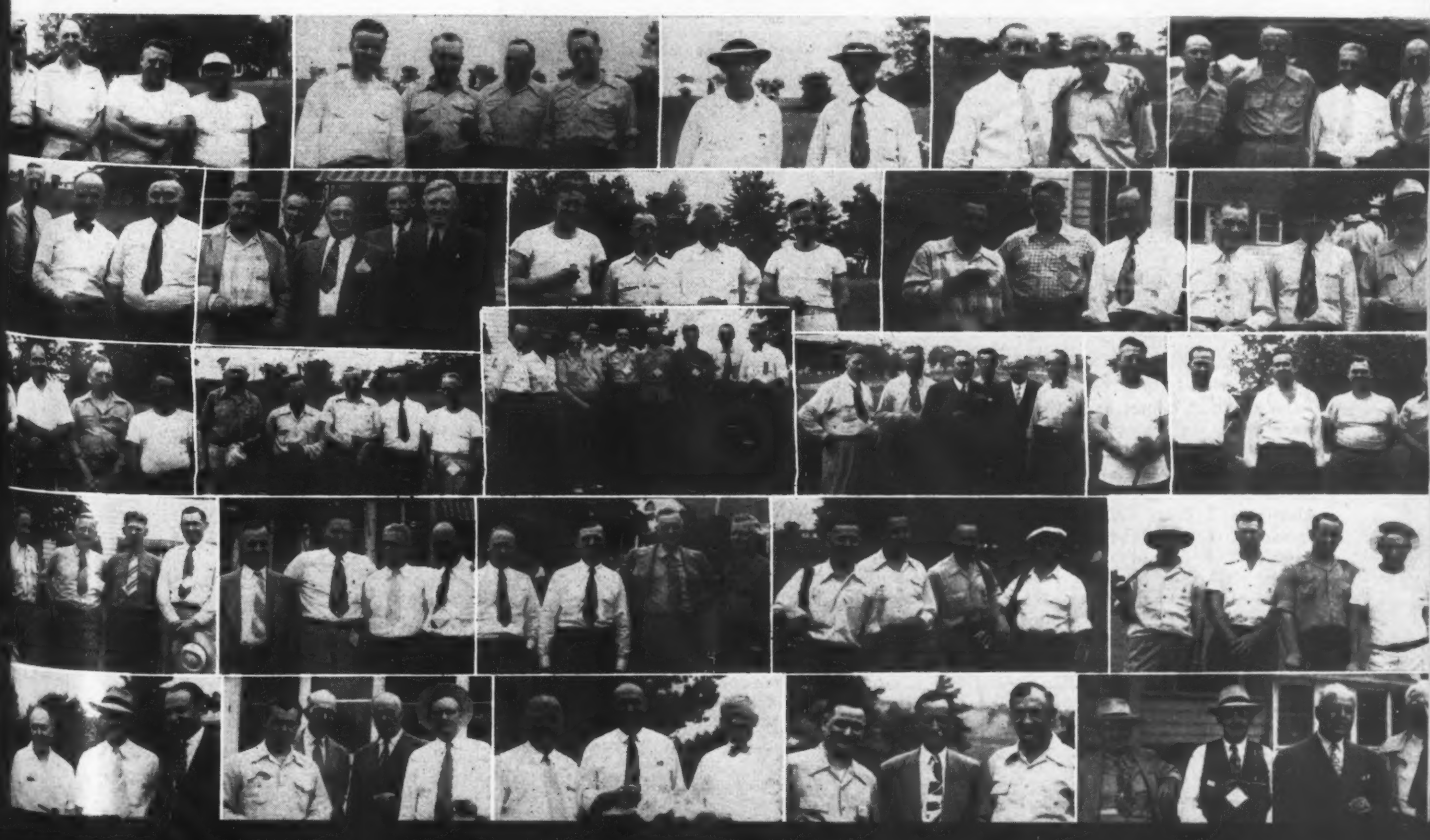
Chicago Foundrymen Hold Day of Fun and Leisure

By L. C. Smith,
Peninsular Grinding Wheel Co.,
Chicago

MEETING as usual at the Lincolnshire Country Club, Chicago Heights, Ill., the Chicago chapter had one of its largest turnouts for its annual outing held Saturday, August 18. Approximately 350 golfers drove golf balls over hill and dale (including the rough) during the morning and afternoon. Those not using the links enjoyed a

From all indications the outing held by the Wisconsin chapter was well attended despite the fact that Ole Sol was ill-mannered and remained behind rain clouds most of the day.

(Photos courtesy John Bing, A. P. Green Fire Brick Co.)



bait casting contest and a little "barn yard golf," or horseshoe pitching. The highlight of the afternoon was the 4 boxing bouts sponsored by the Central A.A.U. and which were enjoyed by everyone. The dinner banquet was held at the club with nearly twelve hundred present. The evening program included the announcing and awarding of the prizes for the golf and horseshoe pitching contests. A floor show concluded the evening session with everyone enjoying the day's festivities.

Quad City Chapter Plans Conference for November

A TWO-DAY regional conference sponsored by the Quad City chapter is now being formulated. Dates have been set for Thursday and Friday, November 15 and 16. Headquarters will be the Hotel Blackhawk, Davenport, Iowa. The general theme of the conference will be "Current and Post-War Problems Confronting Foundrymen." Further details will be announced in future issues of AMERICAN FOUNDRYMAN when they are received from the Quad City chapter.

After the golf games and other activities of the day-long Southern California stag party were over, the members and guests assembled for the banquet dinner. Top (left to right)—Present at the head table, Jim Eppley, Kinney Iron Works; Earl Anderson, Enterprise Iron Works; Geroge Emmett, Los Angeles Steel Casting Co.; H. E. Russill, Eld Metal Co.; Franz Oharek, Mechanical Foundries, Inc.; and Bob Haley, Advance Aluminum & Brass Co. Center (left to right)—A group of happy foundrymen, Fred Tomaseck, I. H. Raber Co.; Charles Lamb, Independent Foundry Supply Co.; Jim Dewald, Bell Foundry Co.; Myron Niesley, California Testing Laboratories; Earl Shomaker, Kay Brunner Steel Products Co., Entertainment Committee Chairman; C. R. McGraw, Long Beach Brass Foundry; Harold Rice, Mechanical Foundries, Inc.; Roy Barner, Snyder Foundry Supply Co., Golf Committee Chairman. Bottom (left to right)—Chapter Officers, past and present, discuss foundry ideas. Bill Emmett, Chapter Vice-President, Los Angeles Steel Casting Co.; Bob Haley, Chapter President, Advance Aluminum & Brass Co.; Al Zima, Chapter Past-President, International Nickel Co., and John Wilson, Chapter Educational Committee Chairman, Climax Molybdenum Co. of Michigan.

So. California Golf Meet Exercises Foundrymen

By James B. Morey, International Nickel Co., Los Angeles

SATURDAY, August 8, was the time and Lakewood Country Club, Long Beach, was the place where some 500 members and guests of the Southern California Chapter spent a day of leisure and fun. Golf attracted a majority of the men present, as they pounded fairways with driver and niblick.

Softball, horseshoe pitching and several track events were participated in by those who failed to exert their energy on the links.

Following the day's activities, the men assembled for the banquet dinner, which was climaxed by a rousing floor show.

Michigan U. Sponsors In-Service Training Course

AN IN-SERVICE training course in "Environmental Controls for Industrial Processes" will be conducted at the University of Michigan, Ann Arbor, Mich., Oct. 2-4, under the sponsorship of the School of Public Health. The course was arranged at the request of the Michigan Industrial Hygiene Association and makes special reference to the foundry and other metal industries.

The courses will be conducted at the School of Public Health building on the University campus in Ann Arbor. Subjects dealing with foundry work were organized by a committee which included S. D. Martin, Saginaw Malleable Iron Div., General Motors Corp., Saginaw, Mich. H. E. Miller, University of Michigan, acted as chairman of this committee.

The course was designed primarily for plant engineers, process engineers and chemists, time study and standards men, personnel supervisors, ventilation engineers, and industrial architects and engineers. However, enrollment is open to others interested in these subjects, registration fee being $5.00. Enrollment is limited to 100 and closes Sept. 25.

50th ANNIVERSARY MEETING

(Continued from Page 26)

several other foreign countries.

It is realized, of course, that difficulties of transportation, rates of exchange and reconstruction may limit attendance from abroad. However, considerable interest has already been shown in several quarters and it is known that a number of European foundrymen are planning to visit the United States in the near future, seeking not only equipment and supplies but also more efficient means of production which will enable them to produce castings at a cost that will help speed the rebuilding of their devastated industries.

On August 24, National A.F.A. President F. J. Walls, International Nickel Co., Detroit, took the first step in formally inviting European foundrymen to attend the 50th Anniversary Convention and Exhibit. In an Air Mail letter to Vincent Delport of England, A.F.A. representative on the International Committee of Foundry Technical Associations, he asked that the invitation of A.F.A. be extended to the Institute of British Foundrymen, the French Foundry Technical Association, and other European groups.

N.E.O. Chapter Active

Under the leadership of Chairman A. C. Denison, Fulton Foundry & Machine Co., Cleveland, the Northeastern Ohio Chapter again will be the "Host Chapter" for an A.F.A. Convention and Exhibit. As early as February 1944, N.E.O. displayed its traditional enthusiasm by inviting A.F.A. to meet in Cleveland in 1946.

Steps have already been taken by the N.E.O. Chapter to organize committees important to the staging of a National Convention. Chairman Denison is expected shortly to appoint members of several committees whose functions begin at an early date. Those foundrymen who have attended A.F.A. meetings in Cleveland in the past are familiar with the facilities and enthusiasm which have enabled the Association to stage there some of its finest conventions.

Chapter Meetings September-October

September 19

Twin City

Curtis Hotel
Minneapolis
J. A. Gitzen
Delta Oil Products Co.
"Core Problems"

September 28

Ontario

Royal Connaught Hotel
Hamilton

Chesapeake

Engineers Club
Baltimore
Werner Finster
Reading Steel Casting Div.,
American Chain & Cable Co.
"Steel Foundry Sand Practice"
National Officers' Night

October 1

Chicago

Chicago Bar Association
General Meeting

Metropolitan

Essex House
Newark
R. V. Elms
Sperry Gyroscope, Inc.
E. C. Hoenicke
Foundry Div., Eaton Mfg. Co.
"Quality"

October 4

Saginaw Valley

Fischer Hotel, Frankenmuth, Mich.
Fred Carl
General Motors Corp., Delco Remy Div., Anderson, Ind.
"Factors in the Production of Non-Ferrous Aircraft Castings"
National Officers' Night

October 5

Western New York

Hotel Touraine, Buffalo
Stuart F. Arnold
National Carbon Co.
"Industrial Relations"

October 8

Cincinnati

Engineering Society Headquarters
C. K. Donoho
American Cast Iron Pipe Co.
"Cast Ferrous Metals"

October 9

Rochester

Seneca Hotel

Northern Illinois-Southern Wisconsin

Faust Hotel, Rockford, Ill.
Dr. Ralph Lee
General Motors Corp.
"Humanics Industry"

October 11

Texas

October 12

Eastern Canada and Newfoundland

Mount Royal Hotel, Montreal

Philadelphia

Engineer's Club
H. W. Dietert
H. W. Dietert Co.
"Mold Atmosphere Control"

Central New York

Onondaga Hotel, Syracuse
Prof. J. Jeffrey
Cornell University
"Ferrous Metallurgy and Engineering"

October 18

Detroit

Rackham Memorial
Round Table Meeting
Gray Iron, Malleable and Brass and Bronze

Abstracts

NOTE: The following references to articles dealing with the many phases of the foundry industry, have been prepared by the staff of *American Foundryman*, from current technical and trade publications.

When copies of the complete articles are desired, photostat copies may be obtained from the Engineering Societies Library, 29 W. 39th St., New York, N. Y.

Aluminum-Base Alloys

CENTRIFUGAL CASTINGS. Northcott, L., and Lee, O. R. J., *"The Centrifugal Casting of Aluminum Alloy Wheels in Sand Moulds,"* Extract from THE JOURNAL OF THE INSTITUTE OF METALS, London, 1945, vol. 71, pp. 93-130.

Wheels have been centrifugally cast in sand molds rotated on a vertical axis, using four aluminum-rich alloys: DTD 304, 2L33, DTD 300, and RR 50 (British Specifications). In centrifugal castings of spoked wheels, porosity tends to be concentrated at the junctions of the arms with the rim and cannot be eliminated by increasing the speed of rotation unless the cross-sections of the arms are larger than in normal practice for static castings. A working rule of 1 in. cross-section of arm for each 10 in. of metal in the rim has been found to represent the *minimum proportions required*. Of the alloys investigated, 2L33 suffers least and DTD 300 most if the arms are of inadequate size. In general, the highest practicable speeds of rotation are desirable for light alloy castings, since the internal centrifugal pressure is naturally low for metal of low density. For the wheel patterns employed, a minimum peripheral speed of 2000 ft./min. was desirable, producing a pressure of 32 lb./in. on the mold wall.

The mechanical properties of samples from three positions in each casting were determined. Although there was only a slight increase in density, test-bars from centrifugal castings in DTD 304 showed an improvement of 15 per cent in tensile strength and 78 per cent in elongation over a static casting. For DTD 300, the corresponding increases were 20 and 60 per cent, respectively. Only light improvements in mechanical properties were obtained with RR 50 and 2L33. In the latter alloy, centrifugal casting had the effect of coarsening the eutectic structure with the particular modification technique employed. When the complete wheels were tested to destruction, the centrifugally cast wheels withstood a maximum load on the average 16 per cent higher than the statically cast wheels.

The macrostructure of the centrifugal castings showed columnar crystals growing from inner vertical surfaces, with equi-axial crystals in the outer zones of the castings. As the speed of rotation increased, the columnar crystals became longer and the equi-axial crystals smaller. Additional castings in other selected alloys provided data which confirmed an explanation of the origin of the structures based on the operation of a centrifuging action during the solidification interval, when the densities of liquid and solid are different.

Calcium

DETERMINATION. *(See Spectrographic Analysis.)*

Casting Defects

MICROPOROSITY. *(See Magnesium-Base Alloys.)*

Centrifugal Castings

ALUMINUM ALLOY. *(See Aluminum-Base Alloys.)*

Chemical Analysis

ALUMINUM DETERMINATION. Wood, C. H., *"The Volumetric Determination of Aluminum in Magnesium Alloys,"* MAGNESIUM REVIEW AND ABSTRACTS (British), April, 1945, vol. 5, no. 2, pp. 31-37.

"An alkalimetric titration method has been developed for the determination of aluminum in magnesium alloys. The excess of free acid in a solution of the alloy is neutralized with sodium hydroxide solution using a screened indicator and the aluminum is then determined, using a second indicator, by titration of the equivalent amount of acid liberated by the addition of sodium citrate. The only interfering metal in the aluminum-containing 'Elektron' alloys is manganese, but a simple correction can be applied."

Clays

BONDING ACTION. Grim, Ralph E., and Cuthbert, E. Leicester, THE BONDING ACTION OF CLAYS, PART I—CLAYS IN GREEN MOLDING SANDS. Report of Investigations—No. 102. 55 pp. Published by the Division of the State Geological Survey, State of Illinois, Urbana, Illinois, 1945.

This report is well described by the authors' own abstract which is reprinted here.

"For more than nine years the Illinois State Geological Survey has been studying intensively the composition, molecular structure, and properties of the clay minerals which are the primary components of clays and shales. The present investigation sought to extend this work to the particular clays used in bonding molding sands with the thought that the more economical production of better castings depends largely on a better understanding of the properties of molding sands and bonding clays. The silica sand component of molding sands has been studied extensively, but hitherto there has been little investigation of the clay.

"Clays are essentially aggregates of extremely small crystalline, usually flake-shaped, particles of one or more kinds of a small group of minerals known as the clay minerals. Since the properties of any clay depend largely on its clay mineral composition, a fundamental basis for the classification of bonding clays is provided. Such a clasification, founded on clay mineral composition, is presented together with detailed determinations of the green strength properties that are characteristics of each class. The bonding value of one of the classes of bonding clays, i.e., halloysite, was discovered during the investigation reported herein.

"A theory of the bonding action of clays in molding sands, based on the individual properties of the clay minerals and the rigid character of the initial absorbed water, is presented which ascribes the bonding action of clay to a "wedge-block" at the junction of the quartz grains rather than to a gluing or adhesive effect. The characteristics peculiar to the various classes of bonding clay, are explainable by this theory. It explains, for example, the unusual air-set strength characteristics of sands bonded with kaolinite or halloysite clay. Such sands develop greatly increased strength without an accompanying water loss when they are allowed to stand in the air after ramming.

"The bulk density characteristics of sands bonded with each class of clay are presented. An explanation for the variation of bulk density with amount of tempering water is suggested, based on the physical character of the water absorbed by the clay."

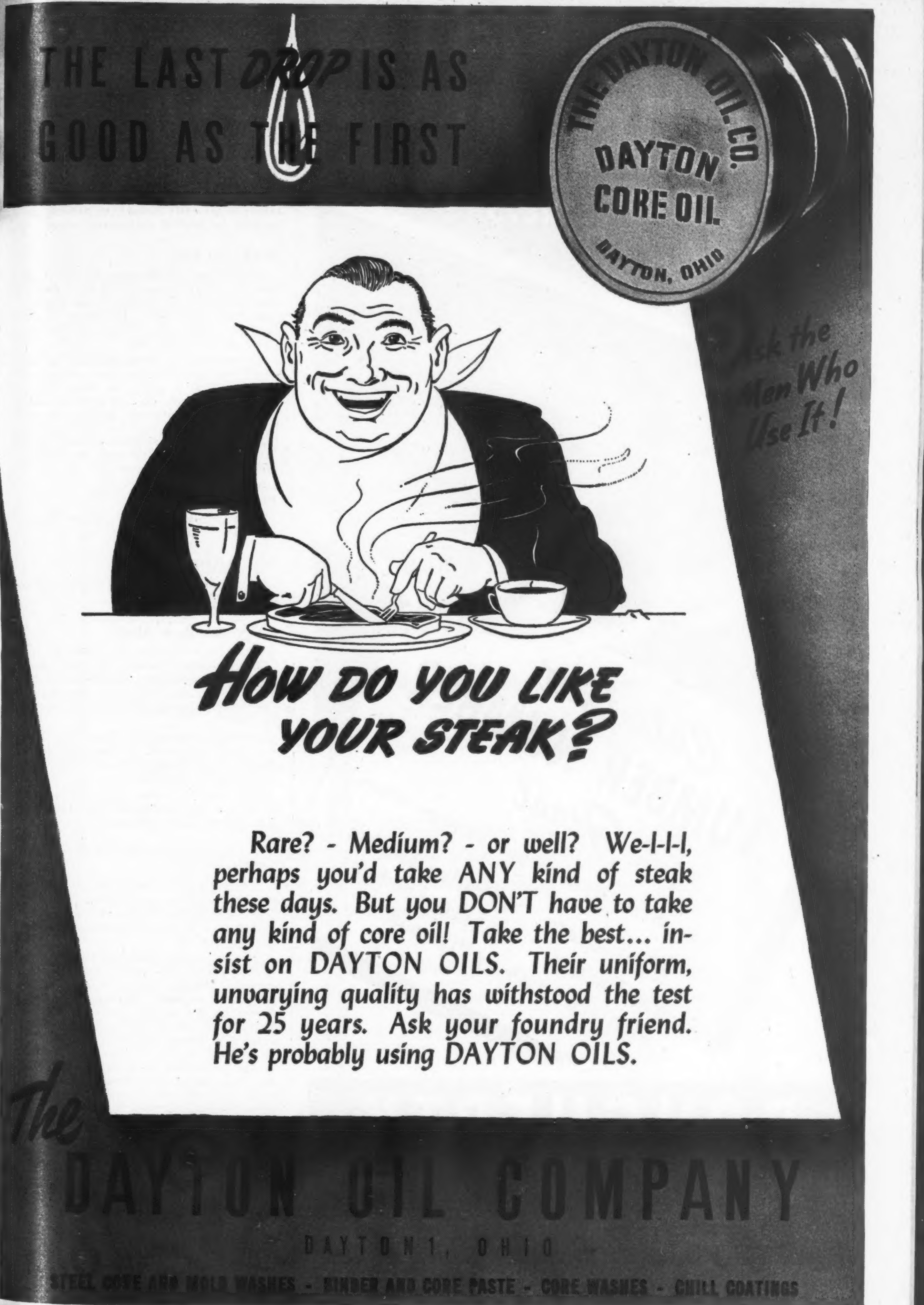
MINERAL COMPOSITION. Grimshaw, R. W., and Roverts, A. L., *"An Investigation of the Constitution of Certain Foundry Bonding Clays,"* Advance Copy, Paper No. 822, The Institute of British Foundrymen, Forty-second Annual Meeting, London, June 15 and 16, 1945, 5 pp.

The authors conducted an investigation to determine by simple means the mineral constitution of certain clays which are used successfully for bonding purposes in British molding sands. The methods which they used for identification included thermal analysis, microscopic examination with the use of dye staining, rehydration studies, and density measurement. Of these perhaps the most useful method is thermal analysis. In this method the thermal changes which take place on heating a clay are used as a means of identification. The authors have included curves showing the thermal reactions of various types of clays, including Wyoming bentonite and American halloysite.

Electric Furnaces

TEMPERATURE CONTROL. Manjoine, M. J., *"Furnace Temperature Control,"* IRON AND STEEL, July, 1945, vol. 18, no. 7, p. 252.

(Abstracts continued on Page 90)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ABSTRACTS

(Continued from Page 88)

A vacuum-tube thermocouple device utilizes two thermocouples of different thermal capacity enclosed within an evacuated glass envelope and connected in series with an unenclosed thermocouple within the furnace. The effect of the instrument is to anticipate temperature changes and thus control the power input early enough to prevent exceeding the desired temperature range.

Gray Cast Iron

TEST BARS. Subcommittee T.S.4 of the Technical Council, I.B.F., *"Tentative Recommended Methods for Casting Cast Iron Test Bars,"* FOUNDRY TRADE JOURNAL, June 28, 1945, vol. 76, no. 1506, pp. 775-176, 180.

The recommendations included in this report are not intended as a standard, but simply as a guide to those having difficulty in producing cast iron test bars. Their recommendations pertain to the method of casting, types of molds, number of bars in a box, feeding heads, mold dressings, patterns, method of running, and temperature of pouring.

Heat Treatment

MAGNESIUM ALLOYS. *(See Magnesium-Base Alloys.)*

Impact Strength

MAGNESIUM. *(See Magnesium-Base Alloys.)*

Magnesium-Base Alloys

ALUMINUM CONTENT. Lardner, E., *"The Aluminum Content of Magnesium-Aluminum Alloys for Heat-Treatment,"* MAGNESIUM REVIEW AND ABSTRACTS (British), January, 1945, vol. 5, no. 1, pp. 18-25.

The two principal factors controlling the tensile properties of magnesium-base alloys are the amount of aluminum and the degree of solution.

This paper describes the results of tests performed to investigate the range of 5 to 12 per cent aluminum.

ALUMINUM DETERMINATION. *(See Chemical Analysis.)*

MICROPOROSITY. Baker, W. A., *"Microporosity in Magnesium Alloy Castings,"* Extract from THE JOURNAL OF THE INSTITUTE OF METALS, London, 1945, vol. 71, pp. 165-204.

The principal problem in casting magnesium alloys is the occurrence of microporosity, which causes leakage under pressure, mechanical weakness, etc. The causes of this porosity in sand castings have been studied, and a theory is advanced to account for its formation and its characteristic features. The porosity is due essentially to freezing shrinkage, but it is shown that dissolved hydrogen may aggravate the trouble; the sources of contamination and methods for the removal of dissolved gas are discussed.

The defect is overcome in practice by careful attention to casting technique, and evidence is presented to illustrate the importance of some of the factors involved. In particular, it is shown that the passage of the metal through the mould in pouring is one of the most important factors influencing the heat

(Abstracts continued on Page 94)

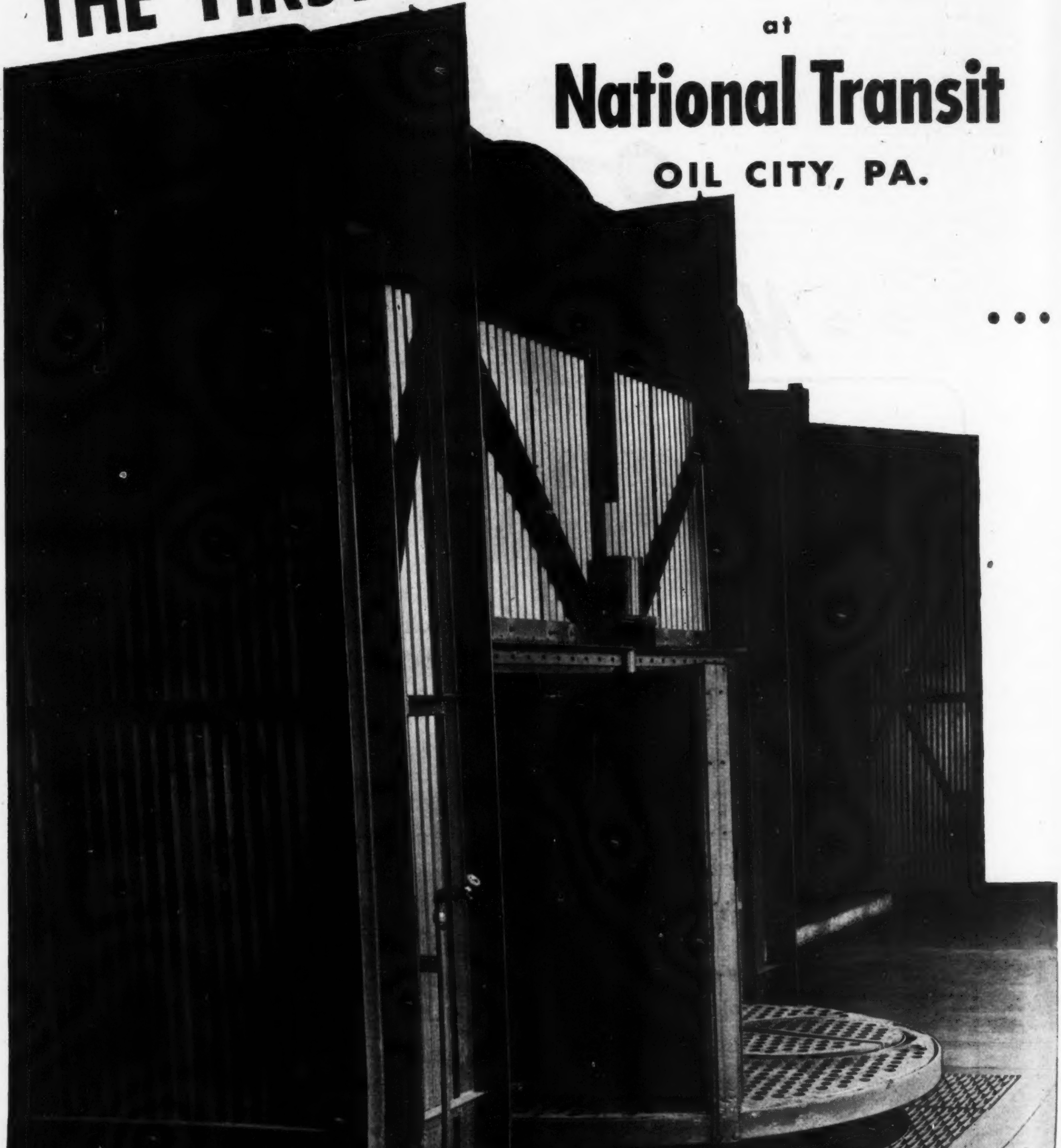
THE FIRST CASTING CLEANED

at

National Transit

OIL CITY, PA.

. . .



ABSTRACTS

(Continued from page 90)

distribution in the casting during solidification, which heat distribution must be controlled to eliminate the defect. Magnesium alloys tend to freeze relatively fast, owing to their low heat content, and consequently favorable temperature gradients are not easily maintained in many castings. Control of the rate of cooling, by control of the pouring temperature and mold temperature, is advocated to overcome this difficulty.

PROPERTIES. Fox, F. A., and Walker, J. L., *"The Impact and Slow Bend Strengths of Magnesium Casting Alloys,"* MAGNESIUM REVIEW AND ABSTRACTS (British), January, 1945, vol. 5, no. 1, pp. 3-9.

This paper reports the results of impact and slow bend tests on a number of magnesium-base alloys. The alloys tested included aluminum-zinc-manganese alloys, an aluminum-tin alloy, and Melpure magnesium and an aluminum-base alloy for purposes of comparison. Impact tests were performed on the Hounsfield balanced impact tester. Slow bend tests were performed with a special attachment used in conjunction with the Hounsfield tensometer. Alloys were tested in the as-cast, annealed, solution treated and fully heat-treated conditions.

Results of the tests are presented in a table which gives the alloy tested, its condition, heat treatment, tensile properties, impact properties, slow bend properties, and comments on the microstructure. The results are also shown graphically.

From the test results a number of the conclusions were drawn, including the following:

Impact values tend to increase as the alloying constituents increase.

Zinc appeared to have a detrimental effect on the properties of heat treated alloys.

Impact properties were best in the solution-treated condition.

Speed is an important factor. In general, slow bend values were below the impact values. This indicates that magnesium alloys can withstand high speed cold bending deformation better than slow speed cold bending deformation.

In the as-cast state, the impact and slow bend properties of alloys containing tin were above those of other alloys. This was not noticeable in the annealed state.

The annealed aluminum-base alloy had properties somewhat above those of the annealed magnesium-base alloys.

Properties of one of the alloys were better in the un-notched state than in the notched state. This emphasized the importance of designing to reduce the number of stress raisers.

PROPERTIES. Walker, J. L., *"An Examination of the Possible Correlation of Hardness and Tensile Strength of Magnesium and Its Alloys,"* MAGNESIUM REVIEW AND ABSTRACTS (British), April, 1945, vol. 5, no. 2, pp. 38-46.

Because of the advantages which result from the relation between tensile strength and hardness in steel alloys, the author decided to investigate the possible correlation between these properties in magnesium-base alloys. This paper describes the methods by which he studied the hardness measurements and the results of his studies.

(Abstracts continued on Page 96)

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ABSTRACTS

(Continued from Page 94)

As a result of his investigations, the author concluded that there is no broad useful relation between hardness and tensile strength of cast or wrought alloys; that the hardness of alloys containing aluminum is related to the aluminum content; that the hardness is somewhat related to the condition of the alloy but not sufficiently so to permit the use of hardness as an indication of the structure; and that it is desirable to use high loads for hardness tests on alloys in the as-cast condition, although low loads may be used on wrought alloys.

Photography

INDUSTRIAL APPLICATIONS. Thorpe, S. H., *"Photography for Research,"* IRON AND STEEL, July, 1945, vol. 18, no. 7, pp. 219-225, 240.

The author describes the various uses for photographic processes or materials in the Brown-Firth Research Laboratories.

Applications of photography discussed include pictures of plant operations, sulphur printing, photographs of macrostructures, photomicrography, photographing indications of defects in various non-destructive test methods, color photography, radiography, recording light traces, and copying.

Quality Control

STEEL TANK SHOE MANUFACTURE. Westman, A. E. R., and Freeman, R. W. S., *"Statistical Control of the Manufacture of Steel Tank Shoes,"* CANADIAN METALS AND METALLURGICAL INDUSTRIES, June, 1945, vol. 8, no. 6, pp. 38-43.

The authors relate how the application of statistical methods enabled them to reduce their percentage of rejects.

Spectrographic Analysis

CALCIUM DETERMINATION. Wood, C. H., *"The Spectrographic Determination of Calcium in the Presence of Large Quantities of Magnesium,"* MAGNESIUM REVIEW AND ABSTRACTS (British), January, 1945, vol. 5, no. 1, pp. 10-17.

In the presence of much magnesium, the accurate determination of calcium by means of chemical analysis is quite difficult. This difficulty is not encountered in the spectrographic method described in this article.

The method is based on the impregnated electrode technique, using a nickel salt solution to give an auxiliary spectrum. A high-voltage spark gives results which are accurate to within plus or minus 2.5 per cent in the range of 2 to 8 per cent CaO. The procedure is accurate and is applicable for all materials rich in magnesium and containing calcium.

Steel

APPLICATIONS OF PHOTOGRAPHY. *(See Photography.)*

BASIC OPEN-HEARTH. Zea, Y. K., *"The Phosphorous Reaction in Basic Open-Hearth Practice,"* Advance Copy, THE IRON AND STEEL INSTITUTE, April, 1945, 46 pp.

The practical applications of the equations for calculating the phosphorus content of the metal on the basis of the slag composition and the bath temperature, established by four investigators, are examined in relation to new temperature data and slag and metal analyses obtained from fifteen casts of basic open-hearth steel. It is found that Schenck and Riess's method gives the best results.

The reversion of phosphorus from slag to metal during casting was studied on twenty-five casts of basic open-hearth steel, first by graphical examination of the slag and metal analyses together with the bath temperature, and second by the application of Schenck's equilibrium diagrams. It is found in that for a given set of working conditions, the rephosphorization likely to occur in the ladle may be estimated quantitatively by the use of Schenck's equilibrium diagrams to establish a ratio of free lime to free iron oxide concentration in the final furnace slag from its composition and the bath temperatures.

The results of this investigation show that rephosphorization during casting is due to a change in the composition of the slag by enrichment of the silica content resulting from its reaction with the fireclay lining of the ladle. It is found that rephosphorization does not occur when the ladle is lined with basic material; and that the degree of rephosphorization, when a fireclay-brick-lined ladle is used, may be controlled to a large extent by keeping the temperature of the slag and metal in the ladle as low as possible, and secondly, by adjusting the slag composition so that, in spite of the reaction with the ladle lining, the basicity of the slag will not fall below a

(Abstracts concluded on Page 98)

ABSTRACTS

(Continued from Page 96)

certain minimum necesary for holding phosphorus. The latter aim can be achieved, when circumstances permit, by increasing the lime content of the slag.

SLAGS. Rait, J. R., and Goldschmidt, H. J., *"The Constitution of Basic Steel Furnace Slags,"* Advance Copy, THE IRON AND STEEL INSTITUTE, April, 1945, 68 pp.

Systems of phase assemblages were deduced from the available phase-diagram data for basic electric reducing and oxidizing slags and basic open-hearth slags. Accordingly, the constitutions of these slags were calculated and compared with the constitutions determined by the X-ray powder method. The agreement between the theoretical and observed results indicates that the systems of phase assemblages are essentially correct. Further confirmation was obtained by correlating the constitutions of a number of basic open hearth slags as observed by Mason (JOURNAL OF THE IRON AND STEEL INSTITUTE, 1944, No. II, p. 69P) with the theoretical results deduced from his analysis. The slags are classified according to their constitutions, the chief characteristics discussed and the various phases described.

The occurrence of merwinite as the main phase in certain basic electric reducing slags and the mode of occurrence of fluorine and TiO_2 was also established. An X-ray method for the quantitative estimation of the amounts of phases was developed for reducing slags.

In electric oxidizing slags the (Fe, Mn, Mg)O solid solution, whose composition and amount varies from slag to slag, is a major phase. The lattice parameters of the RO phases were measured and correlated with their compositions, and the change of spacing during the oxidizing stage was observed. An interesting feature is the appearance of a high-temperature form of $2CaO.SiO_2$, as distinct from the beta form (denoted alpha—$2CaO.SiO_2$), and of merwinite liable to contain manganese-merwinite in solution.

Basic open-hearth finishing slags from a number of steelworks were examined and their constitutions established. The chief phosphate phase is nagelschmidtite or fluorapatite, depending on whether fluospar had been added or not. The solid solution (Fe, Mn, Mg)O occurs in all the slags and, in the more basic slags, co-exists with free (Ca, Mn)O. The co-existence of these two RO phases established by the X-ray method is believed to be a new discovery of considerable practical importance. The amount of the (Ca, Mn)O phase decreases with decreasing basicity until a limiting value is reached at which all the lime is in combination and only one RO phase (Fe, Mn, Mg)O remains. A practical X-ray method of slag control based upon the estimation of these two RO phases is proposed.

STATISTICAL CONTROL. *(See Quality Control.)*

Test Bars

GRAY CAST IRON. *(See Gray Cast Iron.)*

ANALYSIS REPORT

(Continued from Page 76)

the possible sources of sulphur was started. The first analyses of the metal in the scrap bins revealed nothing. Attention was shifted to the electrodes, to the ore, and to all other components of the charge, but the source of the sulphur was not revealed.

Persistent sampling and analyzing of the scrap finally revealed that some of the larger pieces of round stock were free-machining steel. Elimination of this type of scrap immediately resulted in a return to low sulphur and high mechanical properties.

Example No. 5—A chemical laboratory pays for itself many times over. Often in solving a single case the laboratory saves enough money to maintain itself for several years. Value of service to the buyer of castings and of goodwill established is priceless. Follow the case of the lost pearlite and see how chemical analysis solved a costly production problem.

A medium-sized foundry was supplying high-pressure cylinder head castings to a manufacturer. The first operation performed by the manufacturer was annealing, followed by expensive machining before the part was ready for assembly. After final assembly, the equipment was given rigid run-in tests before acceptance by the purchaser.

For reasons not apparent to the manufacturer, numerous lots of cylinder heads, each lot valued in thousands of dollars, were rejected because of porosity and coarse grain structure. The majority of rejections were not discovered until the run-in test had been conducted.

Combined Carbon

Neither the foundry nor the manufacturer exercised any kind of processing or materials control, nor used acceptance tests. Finally, after losing far more than the cost of building, equipping, and staffing laboratories for both parties concerned, the manufacturer had some analyses made. The difference between "good" and "bad" castings was found in the combined carbon.

The "good" castings were pearlitic, containing 0.50 to 0.60 per cent combined carbon, whereas the "bad" castings were ferritic, containing not over 0.10 per cent combined carbon. The common elements were found to be the same in both castings.

As usual, the foundry was blamed for the great variation in combined carbon. The foundry was not able to furnish a record of analyses, but had in storage standard transverse test bars corresponding to each lot of castings. The combined carbon of the transverse bars was in the pearlitic range.

Additional chemical analyses showed that there was no uniformity in the annealing operation. If routine chemical analyses had been made for acceptance and control purposes, the missing pearlite would have been located immediately and valuable time and material saved.

Sand Analysis

Example No. 6—Chemical analyses are of value in every foundry operation and are often a great aid in interpreting the results of other tests. Simple rapid chemical tests frequently save hours of testing by

(Concluded on Page 107)

Tougher Hides

FOR FIGHTING TANKS.....

Figure 1

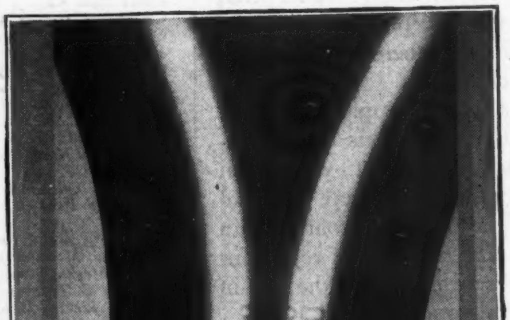
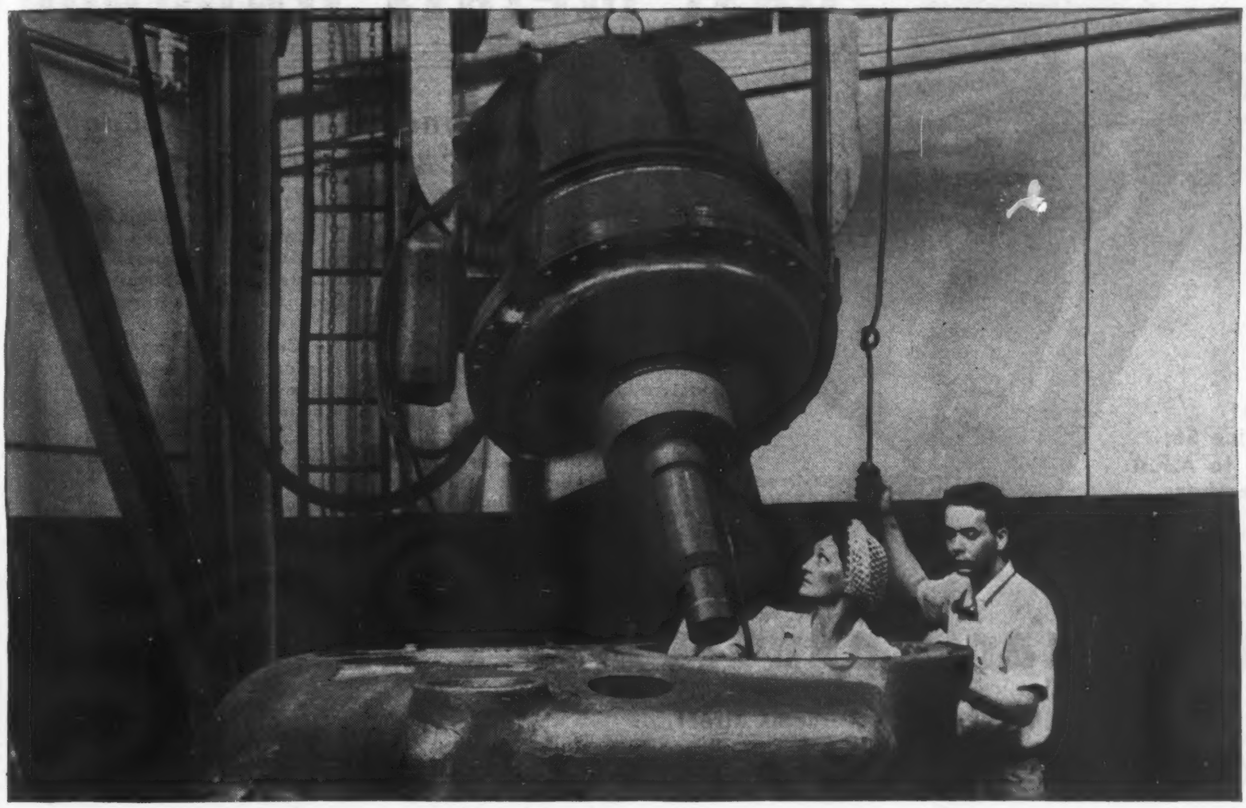
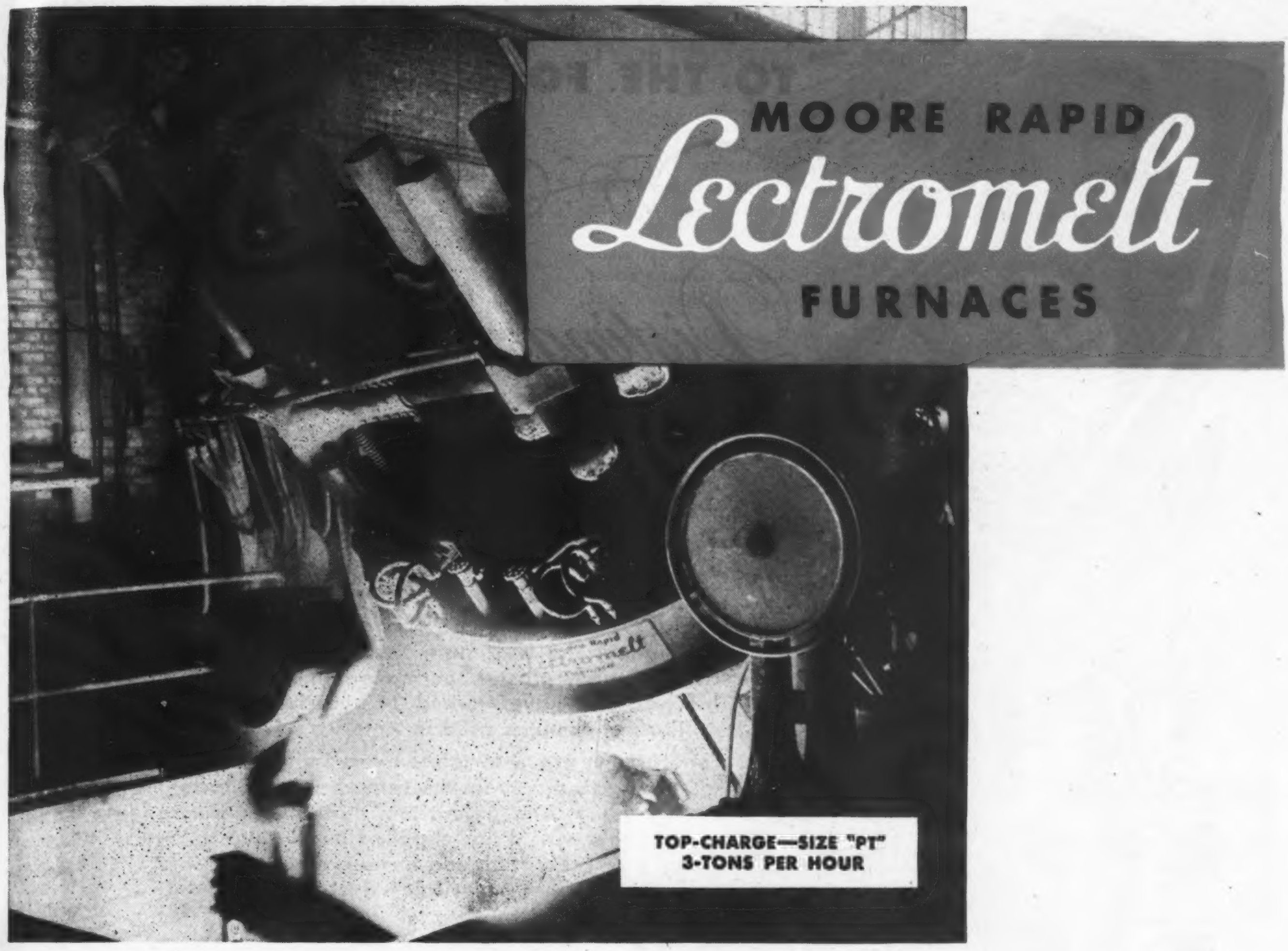


Figure 2





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ANALYSIS REPORT

(Continued from Page 99)

other methods. Since the incident recounted in the following, all new sands received by one foundry laboratory are tested for carbonates before proceeding with the standard sand tests.

The laboratory received a strange sand of very small grain size that looked and felt like an aluminum foundry sand, although the strength was low. A sample was dried for the clay determination, dispersed and siphoned in the usual fashion. It required over 4 hours to remove the clay. The disparity between the results of duplicate determinations was excessive, and the long siphoning period indicated an unusual material.

In the meantime, several small lumps in the original sample were found to be carbonates. Samples of sand, which were analyzed for carbon dioxide by the loss-in-weight method, contained enough marl to make the sand self-fluxing had it been charged into a cupola.

• COMMITTEE REPORT

Time Study Program Can Be Applied Successfully

By Chairman Robert J. Fisher, The Falk Corp., Milwaukee

YOUR Job Evaulation and Time Study Committee has been attempting to bring to your attention practical information showing that it is not a difficult matter to apply modern methods of job evaluation, merit rating, and time study to foundry problems. These methods are tools, which, if properly applied, can, and will, increase production with less effort and fatigue than is at present necessary.

The ideas of job evaluation and merit rating are not entirely new. Many industries are successfully applying these principles, and government agencies encourage the use of them as a basis for wage adjustments. Many labor unions endorse them, particularly when the union has a voice in determining job values.

There are a number of excellent job evaluation plans in use at this

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TIME STUDY REPORT

(Continued from Page 107)

time. By their use, job values are usually established on the following factors: (1) skill and effort required to do the job; (2) responsibility attached; and (3) prevailing working conditions. The factors are often sub-divided and weighted for more precise application, so that the final result will be to have each job properly placed in its relation to the wage structure of the plant.

Merit rating goes hand in hand with job evaluation, and has to do with the man rather than the job. When properly applied, it supplies the information needed to show when "Bill Smith" is eligible to be promoted from a "B" Coremaker to an "A" Coremaker. The points usually considered in merit rating the individual are: (1) quality of work, (2) quantity of work, (3) adaptability or versatility, (4) job knowledge, (5) dependability, and (6) attitude. The degree to which the individual can qualify in these six points will answer the questions—What has he done? What can he do? Can I rely on him? Will further training be a good investment?

Man power shortages during the war period created many problems for executives and supervisors. A properly applied time and motion study program provided a means to alleviate man power shortages. Under such a program in conjunction with a fair wage incentive plan any man possessed of average skill, who has received the proper instructions and training as to the correct methods to be used, and who uses the proper tools, can under normal working conditions meet the performance rate with less effort and far less fatigue than is possible through the application of less scientific methods of rate setting. Installation of such a program should result in increased profits to the company, higher earnings for the employees, better working conditions, less labor turnover, and lowered costs through increased production.

Carbide and Carbon Chemicals Corp., New York, has published a new booklet, "Ethyl Silicate," describing the properties of this silica-depositing material. It is now available for distribution.

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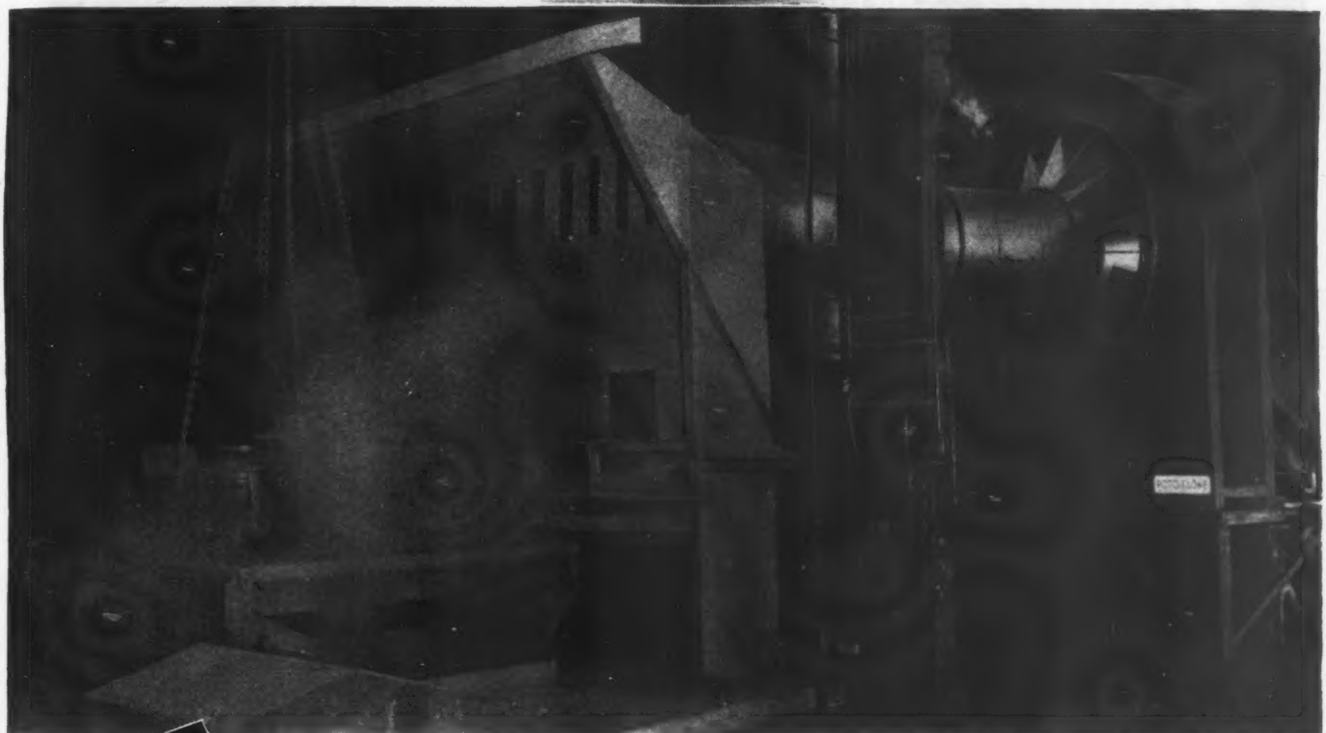

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Shake-out hood connected to a Type W Roto-Clone, as shown above, make an efficient dust control combination and prevents dust and fume dispersion to the surrounding work area. Equipment does not interfere with the operation of the shake-out crane and requires a minimum of space and piping to collect, precipitate and store the dust. The superintendent of the foundry that made the above installation wrote, "Our dust condition was terrible . . . now we have practically a dustless foundry . . . the Roto-Clone really does a job." Write for complete information, and Bulletin No. 274 A.

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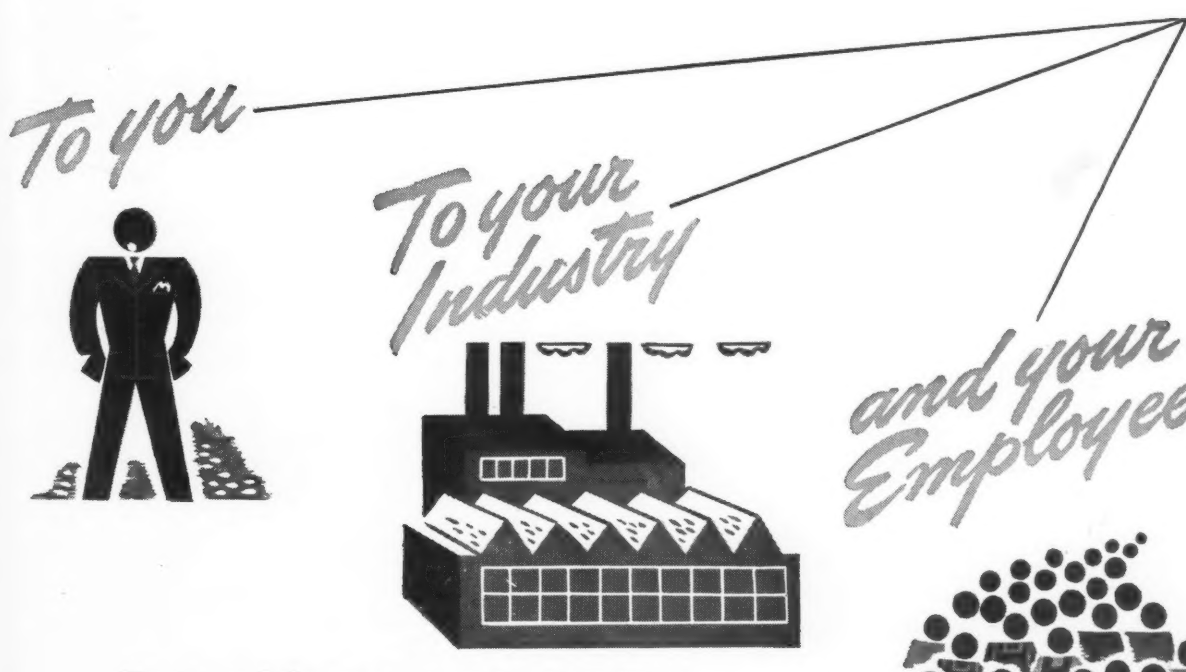

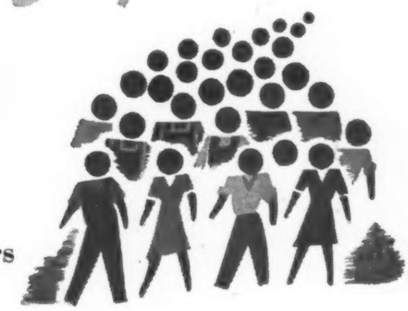

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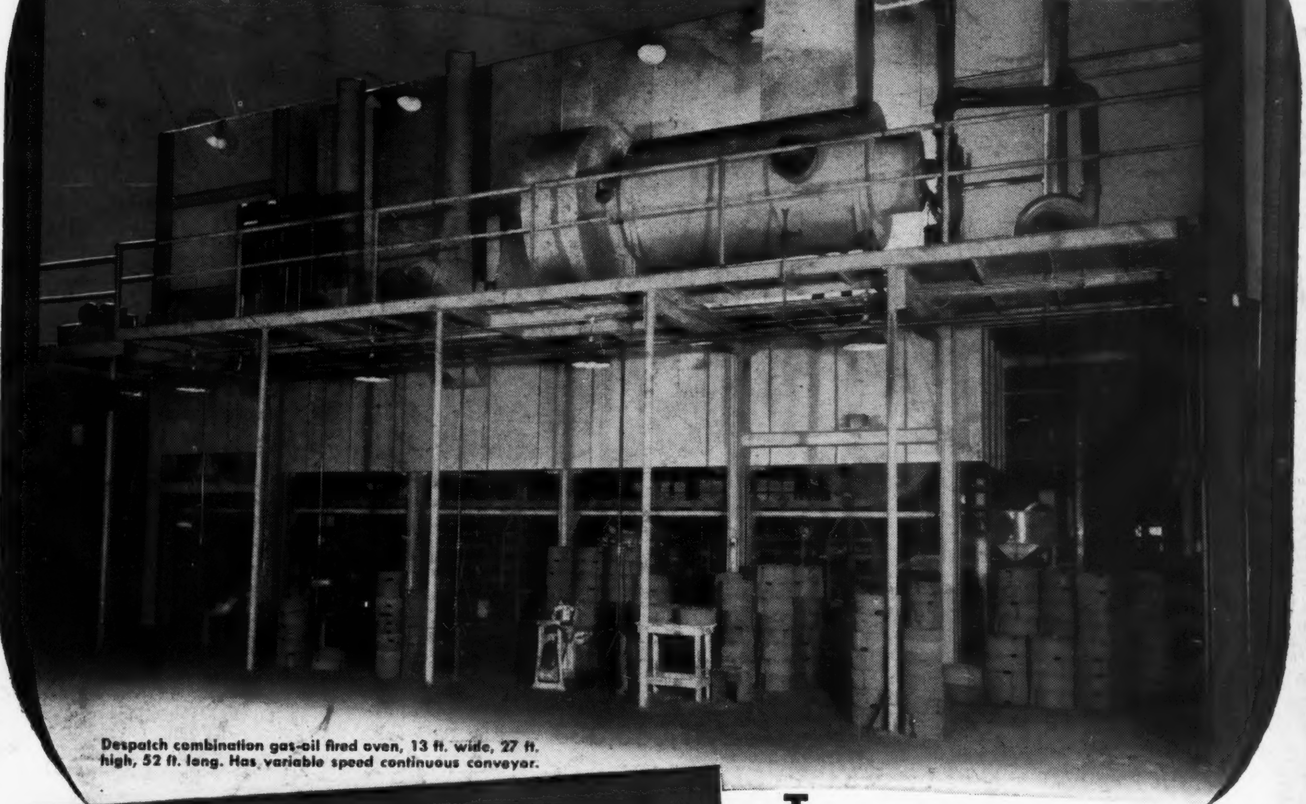

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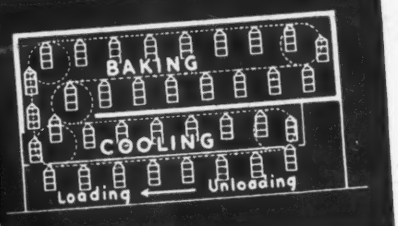

DESPATCH BATCH TYPE OVEN.

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